SUPPORTING TECHNOLOGY FOR AUGMENTED REALITY GAME-BASED LEARNING

Hendrys Fabián Tobar Muñoz

DOCTORAL THESIS

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Gracias a Dios Todopoderoso y a Su Divina Providencia.

Este trabajo está dedicado a mi Reina Omaira que es lo más hermoso de este mundo.

Thanks to God Almighty and His Divine Providence.

This work is dedicated to my Queen Omaira who is the most beautiful of this world
(I swear, this sounds better in Spanish)

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I have always liked games and digital technologies and I have always believed in their educational potential. I remember this chapter in the "*The Simpsons*" series in which Lisa (the "smart" member of the family) dreams with a classroom and a device that takes her to live the battles of Attila the Hun. As a child I used to think that this was an actual possibility dreaming that it could be pretty educational and fun at the same time. But technology was not as advanced back in the day as it is today. Today we are many steps ahead in achieving "Lisa's dream" (my dream). This thesis is part of that.

Been working in my doctorate thesis the last years in Catalonia has shown me two important things: the advancement in technologies for education (Augmented Reality in particular) and the educational potential of games. On the one hand, my studies in AR have shown me a tool that nowadays can be used in learning scenarios, still with obstacles but carrying many opportunities to leverage educational experiences. And on the other hand, games. As I said, I have always liked them and I have been designing and developing them for years. And Catalonia, which has a big tradition on using games for fun, education and as a social catalyzer has made me grow fond on them even more.

This thesis is the result of many hours of study, analysis and reading which regard AR and the use of games for learning. It could have not been possible without the help of the people and institutions I am mentioning next.

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Girona, Catalonia, Spain.

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El Dr. Ramon Fabregat Gesa, (Director)

i la Dra. Silvia Baldiris, (Co-Directora)

CERTIFIQUEM

Que aquest treball, titulat “Supporting Technology for Augmented Reality Game-Based Learning”, que presenta Hendrys Fabián Tobar Muñoz per a l’obtenció del títol de doctor, ha estat realitzat sota la nostra direcció i que compleix els requeriments necessaris.

Silvia Baldiris Ph.D.

Ramon Fabregat Gesa Ph.D.

Girona, 28 d’Abril de 2017

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ACRONYMS

AC: Acceptance Condition

AD: Analysis Document

AO: Augmentable Objects

AR: Augmented Reality

ARGBL: Augmented Reality Game-Based Learning

ARLE: Augmented Reality Learning Experience

ARLO: Augmented Reality Learning Object

BCDS: Broadband Communications and Distributed Systems Group

D: Designer

DBR: Design-Based Research

DM: Design Models

Dv: Developer

ECo: Educational Content

ECr: Evaluatoin Criteria

EI: Evaluation Instrument

EPV: Empirical Performance Validity

ESV: Empirical Structural Validity

GBL: Game-Based Learning

GO: Game Objectives

GUI: Graphical User Interface

HMD: Hedmounted Display

HUD: Head-Up Display

IA: Instructional Activity

IMI: Intrinsic Motivation Inventory

ISCED: International Standard Classification of Education

L: Leader

LMS: Learning Management System

LObj: Learning Objectives

LO: Learning Object

M: Media

MO: Main Objective

Ps: Principles

PC: Personal Computer

PD: Participatory Design

PISA: Programme for International Student Assessment

R: Researcher

RQ: Research Question

SD: Standard Deviation

SD: Specification Document

S1: Section 1

S2: Section 2

SRQ: Sub-Research Question

T: Teacher

TEL: Technology-Enhanced Learning

TPV: Tehoretical Performance Validity

TSV: Theoretical Structural Validity

TUI: Tangible User Interface

VS: Validation Square

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ABSTRACT

Every day, the interest in applying information technology for learning purposes grows. Researchers and developers argue that using technology in learning environments benefits students and teachers. This is to be expected, because technology allows creating experiences that put the student as the center of the learning process. Also, in recent years more and more institutions, teachers and students have access to different types of technology and media, leading to Technology-Enhanced Learning (TEL) to be of upmost importance to teachers, technology developers and policy makers. Among those technologies we can find Augmented Reality (AR) as a technological approach that proposes applications that allow students to interact with the real world trough virtual information, and Game-Based Learning (GBL) a pedagogical approach that advocates for the use of games with learning purposes. This thesis considers the union of both (ARGBL) and studies the implications of using it in the classroom. However, the field of ARGBL remains unexplored. Research is needed to define the concept, demonstrate its advantages and disadvantages, and devise methods and technologies so it can be adopted and used by teachers in real classrooms.

In this thesis, ARGBL is explored and arguments are given in favor of its application in the classrooms. The thesis explores the concept and proposes technologies, theories and recommendations to help teachers and designers to include it in their learning activities.

Thus, in order to explore the concept, the thesis shows a state of art on AR and GBL showing the previous works that support its application. This state of art also shows the strategies that have been used to design and create AR and GBL experiences which allowed the proposals on this thesis to be based on previous findings. Moreover, the state of the art identifies open-issues in the field of ARGBL that remain to be tackled and other aspects of the field are also explored showing examples and previous works.

After contextualizing the reader into the concept and exploring its characteristics, this thesis shows an exploratory scenario where an ARGBL game was used for a reading comprehension activity in a classroom; an AR book involving a game was used. This exploratory scenario was used in a comparative study that studied the differences in performance and motivation among students who used the game and students who did not. Also, the exploratory scenario was used in an observation study that resulted in the identification of the actions performed by students who used the ARGBL game. This observation process focused on identifying the advantages, disadvantages and other implications of applying ARGBL in the classroom. It is argued that using the ARGBL game results in an enjoyable experience for children and also that the experience is enriched by allowing students to perform actions related to cognitive and soft skills.

The exploratory scenario also resulted in the identification of a set of needs to be considered when designing ARGBL experiences for the classroom. Those needs identified that, in order to bring the ARGBL experience in an effective way, it is favorable to include teachers in the design process. However, there is still a gap in the relationship between teachers and AR and GBL designers. To fill this gap, this thesis proposes a method named “Co-CreARGBL” that is meant to guide teachers and professional designers in the creation, deployment and evaluation of ARGBL experiences. Since the method is meant to help in the collaboration of teachers and designers, the “Co-Design for Learning” tradition is adopted and the method is based on previous applications of this tradition. The method is then applied to a set of case studies where teachers and designers collaborated to create ARGBL experiences with different learning objectives. This collaboration spanned and months, and with these case studies the method was validated using the “Validation Square” as a framework for validating Co-CreARGBL as a design method.

The thesis, then, argues for the validity of the method. For this, in order to give arguments for the validity of the method, a validation process is shown where relevant data gathered during the execution of the case studies was analyzed. The data analyzed was gathered under a mixed-method approach

including quantitative and qualitative data. As a result of this, the method is considered to be valid as it shows to be useful, consistent and that the beneficial results of the case studies are related to the use of the method. In this thesis a detailed account of the design process is given. The account shows how the team of teachers and AR and game design professionals were able to deploy an ARGBL game with an accompanying learning experience. This was tested in a natural environment, which rendered the researchers to be able to observe the real consequences and insights into the learning activity and the behavior of teachers and students. At last, the validation of the study shows the advantages of using the method and it also shows that teachers seem to be satisfied and that they comprehend the qualities of the method.

RESUMEN

Cada día hay más interés en aplicar la tecnología informática con objetivos educativos. Investigadores y desarrolladores de tecnología alrededor del mundo argumentan en favor de usar tecnologías que beneficien a estudiantes y profesores. Esto es natural, pues muchas tecnologías permiten crear experiencias que ponen al estudiante como el centro del proceso educativo. Además, en los últimos años más y más instituciones educativas, profesores y estudiantes tienen acceso a distintos tipos de tecnologías y esto ha llevado a que el Aprendizaje Mejorado por Tecnología (TEL, por sus siglas en inglés) sea de una gran importancia para profesores, diseñadores y políticos. Dentro de estas tecnologías encontramos a la Realidad Aumentada (AR, por sus siglas en inglés), una tecnología que propone aplicaciones que permiten a los estudiantes interactuar con el mundo real a través de contenidos virtuales, y el Aprendizaje Basado en Juegos (GBL, por sus siglas en inglés) que aboga por el uso de juegos con objetivos de aprendizaje. Esta tesis considera la unión de ambos (ARGBL) y estudia las implicaciones de usarlos en el aula. Sin embargo, el campo del ARGBL aún está por explorar. Se requieren investigaciones para definir el concepto, demostrar sus ventajas y desventajas y diseñar métodos y tecnologías para que sea usado por profesores en salones de clase reales.

En esta tesis el ARGBL se explora y se presentan argumentos en favor de su aplicación en el aula de clase. La tesis explora el concepto y propone tecnologías, teorías y recomendaciones que ayudan a profesores y diseñadores a incluir el ARGBL en sus actividades de aprendizaje.

El campo del ARGBL aún está por explorar. Por tanto, para explorar el concepto, la tesis muestra un estado del arte en AR y GBL mostrando previos conceptos y trabajos relacionados que soportan su aplicación. Este estado del arte también muestra estrategias que han sido usadas para diseñar y crear experiencias de AR y GBL que permitieron a esta tesis basar sus propuestas en previos hallazgos. Además, el estado del arte identifica un conjunto de problemas abiertos en el campo del ARGBL que quedan por atacar y otros aspectos del campo son explorados mostrando ejemplos y trabajos previos.

Después de contextualizar al lector en el concepto y explorar sus características, esta tesis muestra un escenario exploratorio donde un juego ARGBL fue usado en una actividad de comprensión de lectura en un salón de clase; un libro con AR que incluía un juego fue desarrollado y usado. Este escenario exploratorio fue usado en un estudio comparativo que estudió las diferencias en desempeño y motivación entre estudiantes que usaron el juego y estudiantes que no. También, el escenario exploratorio fue usado en un estudio de observación que resultó en la identificación de las acciones realizadas por los estudiantes que usaron el juego. Este proceso de observación se enfocó en identificar las ventajas, desventajas e implicaciones del uso del ARGBL en el aula. Se argumenta que el uso del juego ARGBL provee una experiencia disfrutable para el estudiante y que la experiencia se enriquece debido a que los estudiantes llevan a cabo acciones relacionadas con procesos cognitivos y con el desarrollo de "habilidades blandas".

El escenario exploratorio también resultó en la identificación de un conjunto de necesidades que se deben considerar cuando se diseñan experiencias ARGBL para el aula de clase. Esas necesidades mostraron que para llevar la experiencia ARGBL de una manera efectiva hace falta involucrar al profesor en el proceso de diseño. Sin embargo, existe una brecha entre profesores y diseñadores de AR y GBL. Para cerrar la brecha, esta tesis propone un método que pretende guiar a profesores y diseñadores profesionales en la creación, despliegue y evaluación de experiencias ARGBL. Ya que el método está pensado para ayudar en la colaboración entre profesores y diseñadores, la tradición de "Co-Diseño para el aprendizaje" fue adoptada y el método está basado en ella. El método fue entonces aplicado a dos casos de estudio y fue validado haciendo uso de ellos.

Finalmente, la tesis argumenta en favor de la validez del método. Para esto, el proceso de validación se muestra usando el análisis de los datos relevantes que fueron recogidos durante la ejecución de los casos de estudio con el objetivo de dar argumentos sobre la validez del método. Los datos se analizaron bajo un enfoque mixto e incluyen datos cualitativos y cuantitativos. Como resultado de esto, el método

se considera válido porque demuestra ser útil, consistente y muestra que los resultados positivos se relacionan con el uso del método. En esta tesis se muestra un recuento detallado del proceso de diseño. El recuento muestra cómo el equipo de profesores y profesionales en diseño de juegos y RA pudieron crear y desplegar un juego ARGBL con su respectiva experiencia de aprendizaje. Dado que esto fue realizado en un entorno de aprendizaje natural los investigadores pudieron observar las implicaciones y consecuencias reales de usar el juego en el aula. Por último, el estudio muestra las ventajas de usar el método y muestra cómo los profesores se ven satisfechos y dicen comprender las cualidades del método.

RESUM

Cada dia hi ha més interès en aplicar la tecnologia informàtica amb objectius educatius. Investigadors i desenvolupadors de tecnologia arreu del món argumenten en favor de fer servir tecnologies que siguin beneficioses per estudiants i professors. Això es natural, per que moltes tecnologies permeten crear experiències que posen a l'estudiant com a centre del procés educatiu. A més, últimament més i més institucions i persones tenen accés a diferents tipus de tecnologies la qual cosa ha fet que l'aprenentatge millorat per la tecnologia (TEL per les seves sigles en anglès) sigui de molta importància per professors, dissenyadors i polítics. Entre aquestes tecnologies podem trobar la Realitat Augmentada (AR, per les seves sigles en anglès), que és una tecnologia que proposa aplicacions que permeten als estudiants interactuar amb el mon real per mitjà de continguts virtuals, i l'Aprenentatge Basat en Jocs que es una proposta pedagògica que advoca per la inclusió de jocs amb objectius de aprenentatge. Aquesta tesi considera la unió de les dues tecnologies (ARGBL) i estudia les implicacions d'usar-la a l'aula. No obstant això, el camp del ARGBL està per explorar. Cal fer recerca que permeti definir el concepte, demostrar les seves avantatges i desavantatges i dissenyar mètodes i tecnologies de tal manera que s'adopti per mestres a salons de classe reals.

En aquesta tesi, l'ARGBL es explorat i es presenten arguments a favor de la seva aplicació al saló de classe. La tesi explora el concepte i proposa tecnologies que ajuden a professors i dissenyadors a incloure el ARGBL dins les seves activitats de aprenentatge. Amb això, la tesi presenta arguments i recomanacions per fer servir activitats de ARGBL.

El camp del ARGBL encara està per explorar. Per tant, per explorar el concepte, aquesta tesi mostra un estat de l'art de l'AR i del GBL mostrant conceptes previs i treballs relacionats que suporten la seva aplicació. Aquest estat del art també mostra estratègies que han estat utilitzades per dissenyar experiències de AR i GBL la qual cosa ha permès que les propostes d'aquesta tesi estiguin basades en troballes prèvies. A més, l'estat de l'art identifica un conjunt de problemes oberts en el camp del ARGBL que queden per atacar. Altres aspectes del camp son explorats mostrant exemples i treballs previs.

Després de la contextualització en el concepte i l'exploració de les seves característiques, aquesta tesi mostra un escenari exploratori on un joc ARGBL va ser utilitzat dins una activitat de comprensió de lectura a un saló de classe; un llibre amb AR que va incloure un joc ha estat desenvolupat i utilitzat. Aquest escenari exploratori va ser utilitzat a un estudi comparatiu que va estudiar les diferencies en el acompliment i la motivació entre estudiants que van fer servir el joc i estudiants que no. També, el l'escenari exploratori va estar utilitzat en un procés de observació que es va enfocar en identificar els avantatges, desavantatges i implicacions de la utilització del ARGBL al saló de classe. Se argumenta que la utilització del joc ARGBL proveeix una experiència gaudible per l'estudiant i que a més l'experiència es enriquida per que es duen a terme accions relacionades amb processos cognitius i del desenvolupament de "habilitats blandes".

El escenari exploratori també va resultar en la identificació d'un conjunt de necessitats que s'han de considerar quan es dissenyen experiències ARGBL per el saló de classe. Aquestes necessitats van demostrar que, per portar la experiència efectivament, s'ha d'incloure al professor en el procés de disseny. No obstant això, existeix una bretxa entre professors i dissenyadors de AR i GBL. Per tal de tancar aquesta bretxa, la tesi proposa un mètode que pretén guiar a professors i dissenyadors durant la creació, desplegament i avaluació de experiències ARGBL. Com que el mètode està pensat per ajudar durant la col·laboració entre professors i dissenyadors, la tradició de "Co-Disseny per l'Aprenentatge" va ser adoptada i el mètode està basat en aplicacions prèvies d'ella. El mètode va ser aplicat a dos casos d'estudi i va estar validat utilitzant-los.

Finalment, la tesi argumenta en favor de la validesa del mètode. Per això, el procés de validació es mostra fent servir l'anàlisi de dades rellevants que van ser recollides durant l'execució dels casos de estudi amb l'objectiu de donar argument sobre la validesa del mètode. Les dades van estar analitzades sota un enfoc mixt que inclou dades qualitatives i quantitatives. Com a resultat d'això, el mètode es

considera vàlid per que demostra ser útil, consistent i per que mostra que els resultats positius que es van obtenir estan relacionats amb l'aplicació del mètode. En aquesta tesi es mostra un recompte detallat del procés de disseny. El recompte mostra com l'equip de professors y professionals del disseny de jocs i RA han pogut desenvolupar i desplegar el joc ARGBL i la seva respectiva experiència educativa. Donat que això va estar fet dins d'un entorn natural, els investigadors van poder observar les implicacions i conseqüències de fer servir el joc a l'aula. Finalment l'estudi també mostra que els professors es veuen satisfets i que entenen les qualitats del mètode.

1 INTRODUCTION

This doctorate thesis is focused in studying the ways in which Augmented Reality Game-Based Learning (ARGBL) —the union between Augmented Reality (AR) and Game-Based Learning (GBL) — technology can be used, created, introduced and evaluated in the classroom. The objectives of this doctorate thesis are, on one hand, to observe the implications of using ARGBL in the classroom, and on the other hand, to explore the possible technological and methodological supports that allow Teachers and Designers to introduce ARGBL in the classroom. In this thesis, the results of the theoretical and practical study conducted during the execution of the doctorate are presented. During this study field observations were conducted and some theoretical approaches were proposed and validated regarding ARGBL technology. It is important to note that in this thesis, some artifacts for education namely games and other software applications are developed, described and/or validated. These artifacts are called by some authors such as Lakhana (2014) as "hard" technologies. However, the "Supporting Technology" mentioned in the title of this thesis points towards "soft" technologies (processes, rules, methods) that are going to be presented as the solution to the needs of Teachers and Designers during ARGBL design endeavors (Lakhana, 2014).

Although in this thesis, some educational and psychological aspects are slightly discussed, the main point of view of the author is from the Technology-Enhanced-Learning (TEL) stance. This thesis discuses several themes regarding AR, GBL, and ARGBL and the ways they are related. For this, it is necessary to introduce the reader to the ideas and motivations that conducted to develop this thesis, the objectives and research questions that guided the process and the way that the results are presented throughout this document.

In this chapter the following is presented: a) the motivation and definition of the problem which the thesis verses about b) the research questions that were used as the main focus of attention c) the objectives that were looked upon this thesis, and d) the way that this document is structured.

1.1 MOTIVATION AND PROBLEM DEFINITION

Through the years, TEL researchers and developers have worked on providing strategies that allow the teachers to include the most advanced and innovative technologies for the learning of their students. This thesis is framed on the principles of TEL by wanting to explore a particular technology, its advantages, disadvantage and implications. In particular, this thesis wants to explore the support given to Teachers and Developers in order to create, design and include ARGBL in learning scenarios. All over the thesis, the main term will be ARGBL, a term that is coined to join the technology of AR (Azuma, 1997, 2001) with the paradigm of GBL (Gee, 2008a; Klopfer, Osterweil, & Salen, 2009; Prensky, 2001a).

AR is basically the superimposing of virtual information on a layer on top of information from the real world (Azuma et al., 2001). AR began as an approach to be used by workers in industrial environments (Caudell & Mizell, 1992) and using technologies that could be too cumbersome by todays standards. However, due to the growth of AR-related technology and its current easier affordability, AR is becoming more and more popular. As with many technologies in the past, AR is gaining adepts and proponents of its use in the classroom as a learning tool. When AR is integrated into the learning/teaching process, positive situations and impacts on learning happen given the characteristics of the technology. Among these characteristics there is Student-Centered Learning, Increased Creativity, benefits related to the way the information is presented (Diegmann, Schmidt-kraepelin, Eynden, & Basten, 2015), increased content understanding, learning language associations, long-term retention and improved collaboration (Radu, 2014) among others. Researchers have studied during the last decade several aspects of using AR in the classroom and the use of AR has been reported extensively in the literature to be benefic for learning in several aspects including motivation, learning gains, and collaboration among others (Bacca, Fabregat, Baldiris, Graf, & Kinshuk, 2014).

AR is focused in the interaction of the student with a learning object and this has proven to be a meaningful experience of learning which in the end is the objective of TEL. Figure 1 shows various examples of AR applications for learning.

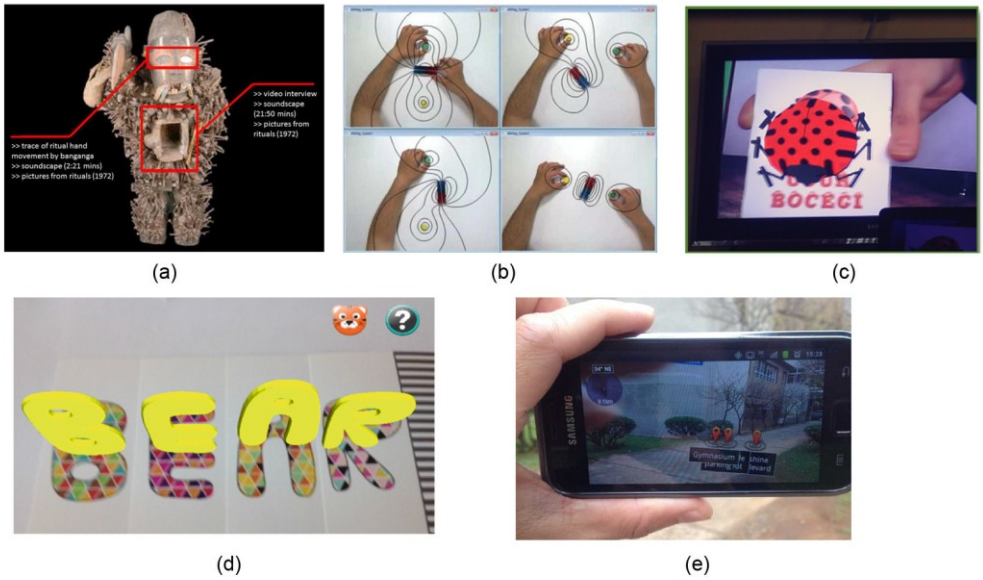


Figure 1. Various examples of AR applications for learning. Image a is taken from, b from (Matsutomo, Miyauchi, Noguchi, & Yamashita, 2012) c and d from (Boonbrahm, Kaewrat, & Boonbrahm, 2015), and e from (Liu & Tsai, 2013)

Figure 1-a show an idol in a museum depicting virtual educational content pointing to interesting aspects of the idol (Simeone & Iaconesi, 2011). In this example AR is useful to "annotate" the real world by superimposing educational content. Figure 1-b depicts an AR app that shows virtual magnetic camps over real magnets showing virtual interactions where AR allows to "see the invisible" (Matsutomo et al., 2012). Figure 1-c and Figure 1-d depict flashcards with augmented 3D models and text where AR allows the real world to "come alive" (Boonbrahm et al., 2015). And finally, Figure 1-e shows an application of Location-Based AR showing Points of Interest with educational content (Liu & Tsai, 2013); Location-Based AR allows educational experiences where virtual educational content is superimposed according to where the user is located.

On the other hand, GBL refers to the use of games in learning processes, a "marriage" between games and learning content (Prensky, 2001a). GBL has also been thoroughly researched by education, technology and psychology experts. In the last one-and-a-half decade, it has shown experiences that render GBL as benefic for learning. As will be explained in later chapters, GBL approached teachers and students with new experiences that achieve meaningful learning. This is based on the fact that games have certain characteristics that allow a "playful" learning (Klopfer et al., 2009) which in turn poses benefits such as motivation, learning from failure, problem-solving, problem-based learning, and a feeling of agency in the process among others (Gee, 2003, 2005a, 2008a, 2008b; Klopfer et al., 2009; Merchant, Goetz, Cifuentes, Keeney-Kennicutt, & Davis, 2014). These characteristics also propose a learning experience that puts the student as the center of the learning process and thus, turning them into the protagonist of their own learning. There are a lot of examples of games used for educational purposes. Some initiatives such as the Games and Impact program (Center for Games and Impact, 2016) have listed and detailed learning games such as some of the shown in Figure 2. The figure shows some games such as *Argument Wars,* used to learn legal concepts of the US legal system; *Sid Meier's Civilization*, which includes actual geographical and historical facts; *Let's Grow!* A board game used to learn about the life cycle; *Peace Maker* used to learn leadership and diplomacy and *Minecraft* used to practice crafting and resource management.

Figure 2. Various examples of games used for learning to illustrate the GBL paradigm (The rights of the images belong to their respective authors)

This thesis was motivated by observing how students do interact and feel motivated by the interactive nature of AR applications and how they seem to engage with the learning content by joining the virtual and the real world. Also, Games are playing an important role in the learning and entertainment scenario of today's learners. Thus, it became interesting to observe, if those technologies have proven

to be useful while used alone, how they would benefit from each other while used jointly. This was the main target of this thesis: to observe ARGBL in action.

The author of this thesis considers that the union of AR and GBL (ARGBL) can be also benefic as AR and games for learning have characteristics which can be complementary. For example, normally AR learning applications are "static" meaning that they are limited to show virtual information over the real world without further interaction; this does not allow the student to live a highly interactive learning experience that shows a more interesting learning experience. Turning the AR application into a game puts a conceptual "playful layer" over the AR interaction which may solve the problem of "static" AR; this can help AR applications to become more interesting and appealing while being true platforms for learning in the classroom. Another characteristic that makes the AR and GBL union viable is that games for learning augmented with AR technology allow students to interact with real learning objects available in the classroom (for example printed materials, maps, and books). The learning associated to the relationship of the learner with their environment has been called by some researchers as "situated learning" which is present during AR learning and it shows benefic to the students and the learning process (Santos et al., 2016; Santos, Ty, et al., 2014; Squire et al., 2007).

The union of AR and games is relatively recent, so it is to expect that the effective inclusion of it into the educational scenario, will take some years as previous efforts of including technologies (PCs, Projectors, Tablets) have shown.

This may be the most adequate moment to introduce ARGBL because currently, there are several developments in the commercial games with AR arena. Games such as *Invizimals®, Pokemon GO®, Wonderbook®* and others have been proposed because developers find them to be appealing to the public and affordable due to the availability of capable devices.

In the BCDS group of the University of Girona, there have been efforts of joining games and AR for learning. The group has conducted observations on the field and explored the aspects of ARGBL in the classroom. This work spawns from those experiences and the author's interest of joining ARGBL and including AR games for learning in the classroom.

The union of AR and GBL seems natural because while AR proposes a different and innovative way to present the information the experience of learning becomes enriched with the playful capabilities of games. The observation of previous works regarding AR and GBL proposed this field as very appealing and promising because as AR and GBL show to be benefic there is still a need to observe the fruits of their union.

Naturally, due to the lack of research on the ARGBL field, there is still a lack of exploration on its aspects as it related to the particularities of the classroom, especially those classrooms that, because of their nature, do not have all the resources to work optimally (such as rural schools). ARGBL may result useful and interesting as AR and GBL have shown to be valuable. Nonetheless, studies are needed to resolve some open-issues such as the theoretical definitions of the relevant constructs regarding ARGBL, the advantages and disadvantages of using ARGBL in the classroom, insights into the interaction of children with ARGBL artifacts and methods for ARGBL to be introduced in the classroom.

There are not many approaches that help the field of ARGBL to consolidate. On one hand, there are not deep observations of the process of learning using AR and Games for learning at the same time. And on the other hand, while the literature shows some experiences of joining and using ARGBL, the examples are scarce and almost never include teachers in the process of designing and developing the games. Although more and more TEL efforts focus on including teachers in the process of designing and deploying educational innovations (Carroll, Chin, Rosson, & Neale, 2000; Cober, Tan, Slotta, So, & Könings, 2015; Sanders, 2002; Sanders & Stappers, 2008) none efforts have shown the inclusion of teachers in the design of games that involve AR. Thus, methodological and technological approaches are needed to overcome this issue and explore the field further.

In an effort to include teachers in the process of designing, deploying and evaluation ARGBL experiences, this thesis proposes that a way to help Teachers and Designers is by adopting the paradigm of "Co-Design for Learning" (Carroll et al., 2000; Penuel, Roschelle, & Shechtman, 2007; Roschelle & Penuel, 2006; Sanders & Stappers, 2008). Co-Design for Learning was chosen because it helps in the collaboration of people with different background acting as creative actors. Co-Design for Learning is part of the ongoing interest in "Co-Creation"; however, unlike Co-Creation, which is a term that applied generally to any creative endeavor where many people participate, Co-Design for Learning is interested specifically in the design of innovations for education. In this thesis, a methodological approach for ARGBL creation with teachers is proposed.

To sum up, this doctorate thesis is interested in the union of AR and GBL for including it in the classroom; also, to observe the process of involving these technologies in learning environments. Moreover, as there are not many theories, strategies and methodologies to support the design, creation and deployment of this type of innovations, this thesis also interests in this issue. Briefly, the problems addressed by this thesis are:

- The lack of studies that study the inclusion of ARGBL and its impact in the classroom.
- The lack of approaches that support teachers and designers in the design and deployment of ARGBL experiences.
- The lack of observations on teachers working to create ARGBL experiences to include in their classroom.

The following sections explain how this problem was addressed in terms of the research questions and objectives.

1.2 RESEARCH QUESTIONS

From the motivations and problems described in the previous section a set of research questions originated. Those research questions arise from the previous experience of this thesis' author and the experience of the BCDS group on TEL and learning environments with AR. The questions also arise from the review of the literature, that as will be seen in later, the ARGBL field remains with several open-issues which create opportunities for research.

There is an increasing interest of some authors of observing students interacting with innovative learning artifacts and there is an opportunity to observe AR and GBL in action because AR and GBL have entered in the lives of people thanks to commercial efforts, and the availability of developments in those fields. Today, there is a high chance of having a game with AR in the pocket devices that many people have. Also, there is a high rate of schools having computers for teaching; today, tablets and smartphones are included in their technological resources.

Given this, in the last decade some efforts including AR and games have been seen like (Barreira et al., 2012; Johnson & Sun, 2013; Maiorescu & Sabou, 2013; H. Tobar-Muñoz, Fabregat, & Baldiris, 2013); but, they remain scarce. Nonetheless, these studies rarely show a deep study on the interactions of students with the technology in their natural environment: the classroom. Since there is a need to recognize the advantages, disadvantages and, in general, the implications of using ARGBL in the classroom the following question is proposed:

RQ1: *What implications are there in the use of ARGBL in the classroom?*

This question desires to know what are the actions, events, individual traits such as motivation, and learning outcomes that occur when ARGBL artifacts are brought into the classroom setting. This includes the students as active participants on the learning and the teachers as users of the learning tools.

To answer this question past experiences, recommendations and theories have to be recognized to clarify and define the games with AR. This recognition brought to attention that the field is quite big, and thus a set of case studies were used in order to answer the question.

The other focus of this thesis' author is to observe ARGBL from the perspective of the teachers as creative and constructive actors. Traditionally, the teachers have seldom participated in the creation of games and/or AR apps for learning. Most of the time teachers participate just as informers of the process. This often leads to the teachers not compromising and engaging with the learning objects that are provided to them. Some studies have demonstrated the need and benefit that comes from the participation of teachers in the creative endeavors that result in technological artifacts for learning (Carroll et al., 2000; Cober et al., 2015; Sanders & Stappers, 2008). Also, it is widely known that teachers cannot afford the time and effort to create their own learning objects and artifacts; this applies also to the case of ARGBL. Thus, the question of how to give support to teachers to create ARGBL resources arises. The author of this thesis subscribes to the notion that it is not enough to give teachers technological artifacts to be used, but rather, that teachers are to be considered important creative actors and choreographers of the learning process. In this sense, the following question is proposed:

RQ2: *How to support teachers and designers in the design, creation and deployment of ARGBL artifacts and experiences?*

Related to this question, there is a need to recognize and study what happens in the classroom when the teachers involve the ARGBL artifacts and experiences that they have designed. To answer this question there is a need to recognize first the needs that the teachers have regarding the creation and the deployment of learning objects and technological artifacts in their classrooms. Within there question, the interest remains in bringing methodological approaches that help teachers and professional designers in order to bring more complex and professional results in the ARGBL experience, and thus favoring the learning experience of the students.

The answer to this question can take many forms. For example, teachers may require authoring tools and/or methodological support. As it will be seen, this thesis leaned towards the latter, because there is a lack of approaches that guide teachers and designers while the authoring tools may result in not very complex or professional results as it is desired.

In the next section it will be seen how these questions became the research objectives.

1.3 OBJECTIVES

The main objective (MO) of this thesis is based on the research questions and it is seen reflected in its title. A general objective of the thesis is:

MO: *To propose supporting technologies for Augmented Reality Game Based Learning inclusion in the classroom.*

Since it is important to identify what the main objective is referring to there is a need to identify the particular objectives that the thesis follows. The thesis's objectives are stated in this section as O1, O2, O3, etc.

O1: *To conduct a literature review on the fields pertaining to the ARGBL field*

As it will be seen in the theoretical development of the thesis, the term AR refers to a set of concepts with different characteristics. Among the characteristics that differentiate the different types of AR there is the type of tracking, the type of display, the devices category which used the AR application, the type of uses given to the app and so on. Thus, it is necessary to conduct an exploration of the term and its implications on ARGBL. Also, there are several perspectives on which games for

learning are considered; however; this thesis focuses in the definitions and uses proposed by previous studies such as (Gee, 2009; Prensky, 2001a; Steinkuehler & Squire, 2014) who propose the uses of games no only as tools to be used, but that go beyond proposing games to be in different ways like architectures for engagement, as an excuse for debating subject themes, as vehicles for content and for evaluation (Steinkuehler & Squire, 2014).

Then, a need arises to explore the different concepts of AR and GBL that, in turn, affect the study of ARGBL. Hence, a literature review on the fields regarding ARGBL was rendered as fundamental to the study.

This objective also proposed the conceptual bases for the rest of the study and the other objectives. The literature review allowed identifying the constructs and previous experiences that gave theoretical and empirical support to this thesis.

O2: *To conduct an exploratory scenario allowing exploring the implications of using ARGBL in the classroom.*

With the field clarified, then it is important to answer the first research question (RQ1) for which a case study was defined and an exploratory scenario was conducted. The exploratory scenario allowed for a deep observation of the actions, during its execution and an analysis of the outcomes after the experience.

O3: *To propose a set of methodological approaches that guide the process of creating and deploying ARGBL experiences involving teachers.*

In order to answer RQ2 a technological approach must be proposed. It is important to consider that often the term "technology" leads to think only in technological artifacts such as software, hardware or tools. In the field of AR and GBL some efforts have been proposed in this sense such as authoring tools (Fernández-Manjón et al., 2012; Radu & MacIntyre, 2009). Nonetheless, the intent of this thesis is to go further and involve the teachers in a deeper and more organic way into the process of design and development of ARGBL experiences in such a way that they appropriate it and use it for the benefit of the students. For this reason, the technological support offered by this thesis is in the form of theoretical contributions that involve methodological constructs to guide such a process.

O4: *To validate the proposed set of methodological approaches in order to check their usefulness.*

With the method proposes, naturally, there is a need to validate the approach. The validation was based on the application of the method to a set of case studies that, because of the nature of the method, spanned months.

With this, the research objectives proposed based on the research questions are stated.

1.4 RESEARCH METHODOLOGY

During the parts of this thesis, there will be different scenarios of research. In the firs part, the study aims to perform a documental research in order to gain conceptual knowledge on relevant prior research regarding ARGBL. Later, this study is interested in performing observations of ARGBL technology in the exploratory scenario. Finally it is interested in performing observations on the process of design and deployment with teachers.

For both cases, the exploratory scenario and the design with teachers, there is a need to perform observations in what some researchers call a "naturalistic environment" (Barab & Squire, 2004); this is opposed to a lab-setting in which most variables are controlled. For this reason, this thesis is framed under the paradigm and methodology of Design-Based Research (DBR) (Barab & Squire, 2004; K.-C.

Chen, Fang, Lee, Oh, & Wong, 2006; The Design-Based Research Collective, 2003; F. Wang & Hannafin, 2005) which will be explained accordingly in chapters 3 and 4. In summary proposers of DBR argue that the methodology (or paradigm) is intended to be used in process that design educational innovations or artifacts for learning scenarios (such as a classroom). Unlike other traditional research methods, DBR proposes that the practitioner participants (Teachers, Students and other stakeholders) on the research are not considered as mere subjects but as active participants on answering the questions of the research; this will be seen during the validation of the method proposed as teachers participated also as researchers. DBR avoids controlled scenarios and considers in the research the context and the "noise" (such as the chaos of a classroom) of the learning setting as an important part of the scenario.

However, while this thesis takes DBR as a general guideline for conducting the research, each of the observations is conducted with mixed-methods approaches. The observations on the implications proposed by objective O1 and the observations needed in objective O4 require the documentation with different means. Mainly the data gathering and analysis was conducted quantitatively and qualitatively. The quantitative part allowed observing general patterns and conclusions while the qualitative part allowed deeper observations and particular aspects on each of the participants.

Under this methodological frame and in order to achieve the propose objectives, the research was conducted as follows:

1. **Literature review about the state of art on ARGBL concepts and creation and other related aspects in order to achieve objective O1**. During this step, the literature review was done performing a search on relevant databases, journals and conferences in the search for previous works relevant to this research. The review was done aiming to look for constructs and concepts that help to define ARGBL. Also, previous experiences and recommendations were held into account as to inform this research.
2. **Definition of a case study to perform the necessary observations stated in objective O2**. Using the information gathered in step 1, a case study was defined and the research was planned to be performed and documented.
3. **Design and Development, of an exploratory scenario allowing performing the observations**. The exploratory scenario was designed to include an artifact designed taking into account the input of teachers. This artifact was a game with AR. Also, the scenario allowed observing students during natural interactions with the game.
4. **Execution of the exploratory scenario in a naturalistic environment.** The observations were done during a naturalistic environment (a classroom). However, a mixed-methods approach was performed to gather documentation to be analyzed. The observations were quantitative and qualitative. The quantitative observations included the learning outcomes of the activity with the ARGBL game and the reported motivation of the students. The qualitative observations were the identified actions that the students performed during the activity.
5. **Identification of needs and context of teachers regarding the creation of ARGBL experiences.** A set of needs and context were identified from the exploratory scenario. This was done as to inform the method to design ARGBL experiences which was proposed later.
6. **Methodological strategy to guide the design of ARGBL experiences with teachers.** This was done to achieve objective O3. The methodological strategy was a method to co-design ARGBL experiences with teachers. The method was done under an iterative approach that included the participation of the teachers (as proposed by DBR). Thus it was designed using a participatory strategy that included a proposition stage, a review with the teachers, testing and refinement.
7. **In order to validate the strategy as proposed by objective O4, build and deploy a set of ARGBL experiences with teachers in a set of case studies**. Using the method a set of teachers and professionals in AR and game design created two ARGBL games to be used in different scenarios. These games were also tested during naturalistic settings with the

participation of the teachers who also acted as researchers and designers (as suggested by DBR).

8. **Conduct the validation process of the method.** The whole process of creating the games using the method was documented. This documentation allowed the validation of the method as a design method. The method was validated using an existing validation framework called "The Validation Square".

These steps were followed in order to conduct the design the necessary artifacts, perform the field study and conduct the field observations.

Further details on the methodological aspects followed by each of the parts of the study are explained in the respective chapters.

1.5 CONTRIBUTIONS

The main objective of this thesis, as explained above is to explore and propose approaches regarding the creation and deployment of ARGBL experiences. The main contributions are organized according to each of the objectives and they are explained in details in next paragraphs

- *Addressing objective O1*: A state for the art is presented as well as a review of studies and applications of AR and GBL in chapter 2. The state of the art presents previous studies and empirical efforts on the creation, design and deployment of AR and GBL applications and experiences. This state of art is presented here and it is of interest for those who wish to observe the actual context and characterization of the ARGBL field. Finally, the state of art mentions some identified open-issues that present opportunities for research and development. The findings were published in a book chapter in (H. Tobar-Muñoz, Fabregat, & Baldiris, 2017).
- *Addressing objective O2:* In this thesis an exploratory scenario was conducted taking as a case study a subtype of games with AR (namely, Image-Based games with AR and augmented books for learning). In this exploratory scenario a field study was conducted in a naturalistic environment following DBR suggestions. The exploratory scenario used an ARGBL game aimed to promote reading comprehension. The observations proposed in O2 were conducted. This contributes with the deep observations and analysis of students interacting with the ARGBL experience in the classroom. The exploratory scenario is shown in chapter 3.
  It is considered that this contribution is an account of what happened in the classroom and what implications does it have to propose an ARGBL for learning. The analysis of the exploratory scenario was done with both: quantitative and qualitative methods. The conclusions of the study are published in a peer-reviewed journal (H. Tobar-Muñoz, Baldiris, & Fabregat, 2017) and in this thesis as well.
- *Addressing objective O3: A* method (named Co-CreARGBL) was proposed to guide teachers and designers in their creation and deployment. The method is based on the paradigm of Co-Design for learning (Roschelle & Penuel, 2006) and it is aimed at guiding the collaborative creation of ARGBL including teachers; for this, this is one of the main contributions of this thesis. The method is described in chapter 4. The structure of the method and other details were published in (H. Tobar-Muñoz, Baldiris, & Fabregat, 2016a, 2016b; H. Tobar-Muñoz, Fabregat, & Baldiris, 2016).
- *Addressing objective O4:* This thesis conducted a set of two case studies in order to illustrate the method and validate it. Two teams including rural school teachers were involved in the process of creating, designing, developing and deploying an ARGBL game and an accompanying instructional activity which were published in a book with the help of the teachers (Hurtado et al., 2016; López Panesso, Chate Ramos, Pinto Muñoz, Mosquera Melenge, & Tobar-Muñoz, 2016). Teachers contributed with their knowledge of the context of their students, the educational needs and the educational content. The case studies were used in a validation

process that was guided by the Validation Square Framework (Seepersad, Pedersen, Emblemsvåg, Bailey, & Allen, 2006). The case studies and the validation process not only validate the usefulness of the method but gives an account on the use of Co-Design methods involving teachers which may become an empirical factor for other endeavors that wish to involve teachers in the creative process of creating educational resources.

Other noteworthy contributions of this thesis are the various ARGBL games and instructional activities created during the execution of the thesis. These contributions are in the form of educational software that is meant to be used in learning scenarios. The games created are:

- *Gremlings in my Mirror:* An ARGBL game for mathematics. This game is not discussed here but it appears in the master thesis done prior to this doctorate thesis by the same researcher (H. Tobar-Muñoz et al., 2013). However, this game served as an experience to recognize the capabilities of ARGBL games.
- *Ole, el Elfo Cierraojos:* An AR game-book for promoting reading comprehension. This was used during the exploratory scenario.
- *Cuetaya: Tierra de Colores:* A game meant to teach traditional values on an indigenous school.
- *Una Aventura por el Cauca:* A game used to teach concepts of social sciences in a local region of Colombia. Both, this and "Cuetaya" were co-designed with teachers during the cases studies and they were used during the validation of the method.

These games are meant to be used by any teacher as they constitute open learning resources. The accompanying website (http://bcds.udg.edu/ARGBL/) has more information on the games and the actual software available for download.

1.6 DOCUMENT STRUCTURE

This thesis document is divided into four parts which in turn are divided into chapters with their respective sections. The parts, chapters and sections develop the study in order to document it and to report the results as evidence for the accomplishment of the objectives and the answering of the research questions. This section explains in summary this division.

The present chapter, *Chapter 1*, shows the introduction to the topic of ARGBL, a general vision of the problem addressed by the thesis and other general aspects.

The document is divided into part. ***Part One: State of Art*** includes only *Chapter 2* with the description of the study on the literature review conducted in order to accomplish O1. Each section on this chapter shows an introduction to several themes interesting to this research among which it can be found AR, GBL and authoring and design of AR and GBL experiences. At the end of the chapter, a set of conclusions originating from the literature review and a set of open-issues are discussed.

Part Two: ARGBL Exploratory Scenario shows the addressing of O2. This part includes *Chapter 3* in which the exploratory scenario conducted with the inclusion of ARGBL in a learning activity is described. The chapter shows observations and analyses of the interaction of children with an ARGBL game-book. The chapter describes the design, development of the game used and the design of the design experiment that was conducted. The chapter shows the quantitative and qualitative results of the field study conducted in a naturalistic environment. The main contributions of this chapter include the report of the exploratory scenario, the analysis of the observations, and the lessons learned that render the needs for ta method aimed to support the design of ARGBL experiences including teachers.

Part Three Approach for ARGBL Design: includes three chapters. *Chapter 4* shows the description of a method aimed to guide and support the design and deployment of ARGBL experiences including

teachers as creative actors. *Chapter 5* shows the cases studies that were used to illustrate and validate the method. And finally, *Chapter 6* shows the process of validation.

Additional chapters are included in ***Part Four: Conclusions*** which includes *Chapter 7* with the final summary of the thesis, discussions on the results, conclusions, limitations of the study and future work. *Chapter 8* shows the Bibliography. The thesis also presents, at the end of the document, a set of appendixes meant to report and inform on further information or other interesting aspects of the thesis that because of space issues were not included in the respective chapters.

Along this thesis the chapters will present references to an "accompanying website". This site is meant to include other evidences, information or other elements that are not suitable for a printed medium such as software, DataSets or videos, and thus are displayed and referenced for downloading. The accompanying website refers to http://bcds.udg.edu/ARGBL/Thesis/.

PART ONE: STATE OF THE ART

2 STATE OF ART

Since GBL and AR applications to education have received attention for their potential in the last decade, researchers around the world have strived to come up with theories, facts and experiences to explain and demonstrate their characteristics, features affordances and capabilities. This study is an effort to support the technology for the inclusion of AR and GBL technologies and practices in the classroom and thus, it is supported in previous research.

Hence, in this chapter, the literature review is shown. The chapter describes the most relevant findings, theories and discussion that have been observed until now for expert researchers around the globe in order to contextualize the reader in the basis of this study.

This state of art results from a review of the literature where prominent journals on the topics, conference proceedings depicting interesting experiences and some web pages and pertinent resources found on the web have been explored, surveyed and analyzed to gather the conclusions shown here.

This chapter depicts the current state of research and development regarding GBL and AR for education and is intended to portrait the advances in the area as well as the open issues remaining.

This chapter is divided in two main areas: AR (emphasizing in the applications to Learning) and GBL. For each one, it shows the generalities and relevant theories. Also, each area shows previous experiences in the application of the technologies and the support for teachers and the classroom. In an additional, narrower, area a review of experiences on the use of AR applied to learning and GBL is shown. After the review, a set of conclusions are shown describing the current state of the art and the considered missing gaps.

2.1 AUGMENTED REALITY

Augmented Reality is, in essence, a system that "augments" the real world by overlaying virtual content. The first appearance of the concept dates back to the 1960's by Morton Heilig, a photographer who applied the concept in his prototype "Sensorama"(Heilig, 1962) with cinematic purposes (Carmigniani et al., 2011). But, it was not until the nineties when Tom Caudell and David Mizell coined the term to be used in a prototype to assists workers in the aeronautic industry (Caudell & Mizell, 1992).

Naturally, the term has advanced with the introduction of new technologies and practices. Currently the most widely accepted definition is that of Azuma (1997; 2001) who defines it as a system that: "*Combines real and virtual objects in a real environment; Runs interactively, and in real time; Registers (aligns) real and virtual objects with each other*".

This definition, nonetheless, has had many interpretations for the "alignment", "registering" and the "real and virtual objects" parts. For example, many works understand and focus the AR aspect in the visual interpretation of the real world and the overlaying of 3D elements over it; others understand it as the alignment of virtual representations of the user into a real world map and others see it as the overlaying of information based on a device's orientation. This issue has been observed by Cheng & Tsai (2012) who state that AR applications features differ based on their tracking and registration (the actual techniques used to interpret the real world and overlay virtual elements on it (Papagiannakis, Singh, & Magnenat-Thalmann, 2008)). Thus they re-coin the types of AR into (1) Image-based and (2) Location-based.

Figure 3 depicts a comparison between both types of AR as observed by Cheng & Tsai.

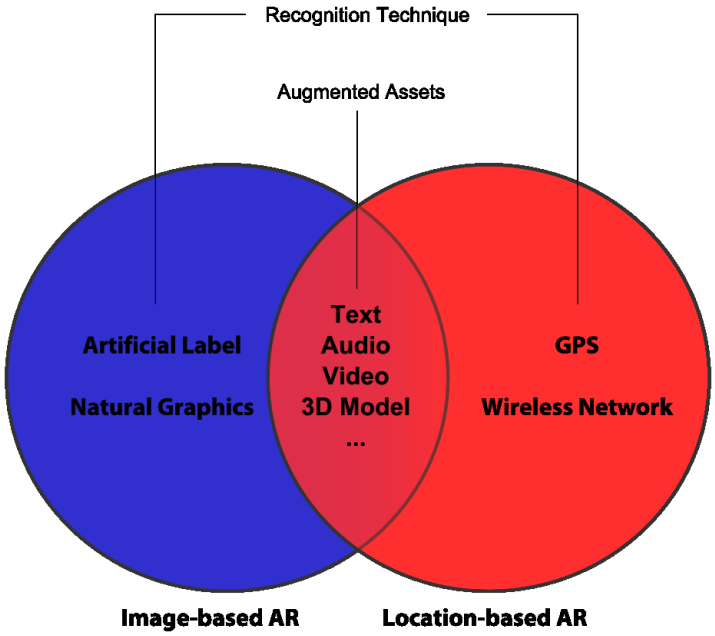


Figure 3. Comparison of Image-Based and Location-Based AR (Cheng & Tsai, 2012)

It is relatively easy to find examples of both types of AR applications. For example the BCDS group has developed *Gremlings in my Mirror* (Figure 4 – (1)), an educational *Image-based* application that uses AR-markers as input interface (H. F. Tobar-Muñoz, Fabregat, & Baldiris, 2014) and *eFlors* (Figure 4 – (2)) a *Location-based* application that used GPS location for the popular "Temps de Flors" fair in Girona. It allowed visitors to use their mobile phones to locate the different flower displays along other media like, for example, a video of the author on a particular work (BCDS, 2014) .

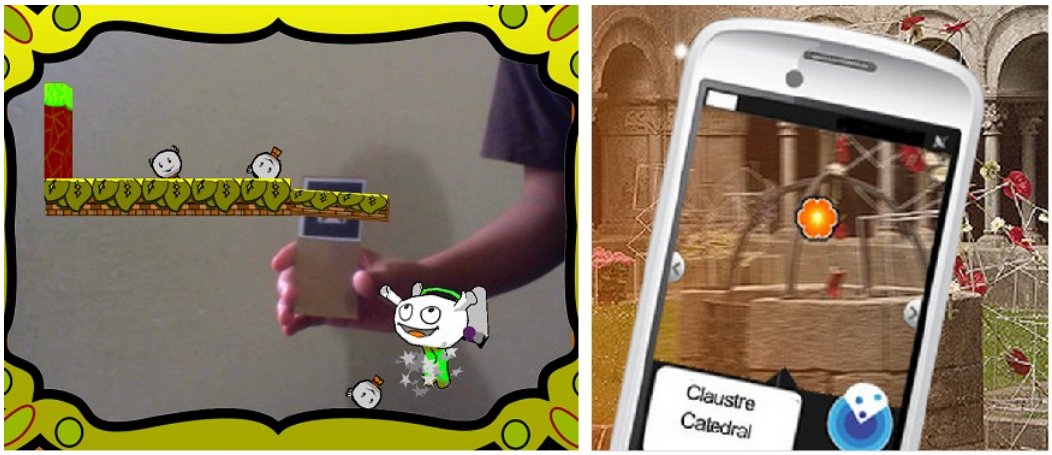


Figure 4. Examples of AR applications. (1) is "Gremlings in my Mirror" an Image-Based AR application and (2) is eFlors, a Location-Based AR application

Also, it is important to remark the various types of interactive AR. AR allows for several types of interactive experiences. Some experiences are "shallow" meaning that they are limited to show virtual information over some tracked element in the real world, while not allowing interaction. Examples of this are applications such as Mirracle (Blum, Kleeberger, Bichlmeier, & Navab, 2012), which displays anatomical organs over the body of the user, but it is limited to superimpose 3Dmodels over the image of the user and moving with them. Of course, AR's interactive nature is more visible in applications with higher interactive features. In these types of applications, the users are able to interact with virtual and/or real elements in one or two ways limited by the applications features. For example, the works by Ibanez, Di-Serio, Villaran-Molina, & Delgado-Kloos (2014; 2014) show applications where students can interact with 3D elements mimicking circuit elements. Finally, highly interactive AR experiences allow many types of interactions over many real and virtual elements. These types of AR experiences, while harder to achieve benefit the interactive experience by allowing the users to feel sensory immersion, navigation and manipulation which might foster feelings of presence (Bokyung, 2009).

AR has had plenty of applications, including commercial games, advertisements and utilities. Also, nowadays several low-level techniques have been developed to work with AR. Just to cite some, the location-based applications often rely on the support of GPS data obtained by the system. And, obtaining GPS data in mobile systems is relatively easy nowadays, especially when working with premade libraries and frameworks like the Android Development Toolkit (ADT) ("Android Developers," 2014). There are also commercial options for the non-programmer user like the Layar ("Layar," 2014) and the Metaio ("Metaio," 2014) platforms; both feature authoring tools and other resources to make easier the development of location-based and image-based applications. These and other AR development platforms most likely rely on Computer Vision algorithms and methods for image registration related to video tracking. In general words, those methods consist of two stages: tracking and reconstructing/recognizing (Carmigniani et al., 2011). As evidence of the development of those techniques, Zhou, Duh and Billinghurst (2008) found that roughly 60% of the trending papers they reviewed were related to tracking, interaction and calibration techniques being discussed instead of actual applications.

The description of those techniques and applications are beyond the reach of the present thesis, but, the current literature shows that several low-level techniques are already deployed to be used by application builders so they just have to worry for the actual application and not for basic activities like computer-vision algorithms and user interface techniques. In this sense, we can highlight libraries and platforms that can be used to deliver AR applications based on computer-vision techniques like the

ARToolkit[1], (and its derived platforms, Wikitude[2] and the Studierstube[3]) among others. They have shown to be used widely in the research and development of AR applications.

This work is interested mainly in the application of AR to education; hence, here we show the current state of research and development of AR for learning.

2.1.1 AUGMENTED REALITY FOR LEARNING

AR presents several features that makes it a good tool for learning, thus it has been applied and considered both, theoretically and empirically as a tool to be used in classrooms all over the world. Some authors believe that AR has vast potential and numerous benefits for learning (Yuen, Yaoyuneyong, & Johnson, 2011). In Yuen's Overview (Yuen et al., 2011) authors claim that AR for learning has potential to:

- Engage, motivate and stimulate students
- Help teach subjects where it is not easy to gain real world experience
- Enhance collaboration between students and instructors, and among students
- Foster students creativity and imagination
- Help students take control of their learning
- Create an authentic learning environment suitable to various learning styles.

The same authors propose 5 keys to the application of AR in learning environments. These are:

- AR Books
- AR Games
- Discovery-Based Learning
- Object Modeling
- Skills training.

It seems like there is an increasing interest in performing AR for Learning reviews of literature like (Bacca et al., 2014; Bitter & Corral, 2014; Diegmann et al., 2015; Radu, 2014). Most of them revolve around the potential and benefits of AR applied to learning. For example Radu (Radu, 2014) lists and supports these benefits:

- Increased content understanding
- Learning spatial structure and function
- Learning language associations
- Long-term memory retention
- Improved physical task performance
- Improved collaboration

In the same line of thought Diegmann et al. (Diegmann et al., 2015) mix Radu's and Yuen's observations by classifying the works reviewed in both dimensions: the directions and benefits proposed by the previous authors. They also find how AR for learning has the following benefits:

- Reduced Costs
- Student Centered Learning

[1] http://www.hitl.washington.edu/artoolkit/
[2] http://www.wikitude.com/
[3] http://studierstube.icg.tugraz.at/main.php

- Increased Creativity
- Presentation[of the content]-related benefits

Bitter and Corral's review (Bitter & Corral, 2014) also concludes, based on existing literature, that AR is indeed a good tool for learning and that it has been applied in several fields of cognition, ranging from simple elementary math to Astronomy, Chemistry and so on.

One of the most important aspects of AR for learning is its affordances. AR theorists have observed that AR allows many types of learning experiences. For example authors argue that AR is useful for science because it promotes *Inquiry-based learning, practical skills, spatial ability, conceptual change* and *conceptual understanding* (Cheng & Tsai, 2012). AR has shown to be very good at creating "*hybrid learning environments that combine digital and physical objects, thereby facilitating the development of process skills such as critical thinking, problem solving, and communicating*" (Dunleavy, Dede, & Mitchell, 2008). Location-Based AR is able to afford a significant narrative where users relate learning content with some real-world location. This was shown in studies like (Dunleavy et al., 2008; Squire, 2010; Stefan & Moldoveanu, 2013). It also allows to enable *learning content in 3D perspectives*, *ubiquitous, collaborative and situated learning, learners' senses of presence, immediacy, and immersion, visualizing the invisible*, and *bridging formal and informal learning* according to (Wu, Lee, Chang, & Liang, 2013). Image-Based AR approaches have the affordances of *enhancing spatial knowledge representations and* promoting positive Psychological states such as *motivation, flow, cognitive benefits, reflection, and sense of presence* (Ibáñez et al., 2014).

But, reviewed works also mention some limitations of obstacles to the adoption of AR in the classroom like: teachers/manager not being interested, internet connectivity, budget and other practical considerations. Radu mentions not only limitations, but detriments like attentions tunneling and usability difficulties. The attention tunneling issue is mentioned in several reviews as one of the most detrimental factors of applying AR in the classroom (Bitter & Corral, 2014; O'Shea, Dede, & Cherian, 2011; Radu, 2014). It refers to the fact that it is detrimental to the learning when the learner has a high cognitive load and they are inexperienced in the use of the learning the medium like AR. Nonetheless, authors show also that while this is an obstacle right now, they have hope in that this will be less of a factor in the future when technology permeates the educational world. Indeed, they trust the learners' attitude towards the AR technology based in observations of children preferring the novel tool instead of more traditional approaches.

In the learning field AR has shown several experiences. The study of Santos et al. (2014) is a great example of this claim. Santos and his fellow researchers completed an exhaustive meta-analysis of the works found on literature regarding Augmented Reality Learning Experiences (ARLEs). Their results show interesting conclusions like:

- AR has unique affordances that can affect the learning experience. This include:
    - The ability to "annotate" the world: to include virtual elements tagging in some way the real world with educational purposes.
    - Contextual visualization: to display virtual content according to a specific context.
    - Vision-haptic visualization: to enable *embodied interactions* with the virtual content.
- ARLE's have proven to be effective in improving the performance of students. However authors warn that the generalization of this must be taken carefully since the variability of the effect size they calculated is high.
- ARLE's have been evaluated with several techniques. This is interesting and shows the interest of researchers to validate and observe the implications of applying AR to learning.
- ARLE's' affordances are supported by some learning theories. The authors show how existing learning theories explain the effectiveness of AR. The theories include multimedia learning theory, experiential learning and animate vision theory.
- Adapting AR technology changes the learning experience and may afford new compelling experiences that lead to better learning.

Santos et al.'s work is timely and relevant for this thesis. Thus, here are commented some of it results referring to some of the works reviewed by them. Those works, jointly, show the feasibility and effectiveness of AR applied to education.

Perhaps, the main conclusion of this latest meta-analysis is a quantitative proof of AR effectiveness in increasing the performance of the students. This conclusion comes from an application of an effect size formula on the quantitative results reports in seven studies. According to this, AR has a moderate effect (effect size of 0.56) on the performance of students which is very important considering that the effect size of educational technology is 0.35 (Tamim, Bernard, Borokhovski, Abrami, & Schmid, 2011).

The display device is an important factor to observe in ARLEs. Display devices and their classification have been proposed in previous works (Azuma et al., 2001; Krevelen & Poelman, 2010; H. Tobar-Muñoz et al., 2013). Often, authors observe how AR display devices are divided among Desktop Monitor (Santos, Chen, et al., 2014) or "Spatial" (Krevelen & Poelman, 2010); "Handheld" and "Headworn" devices (Azuma et al., 2001; Krevelen & Poelman, 2010; Santos, Chen, et al., 2014); and "Projective" devices (Azuma et al., 2001) considered as projective over the real element (Azuma et al., 2001) and as an overhead projector (Santos, Chen, et al., 2014).

The following table depicts briefly some examples.

Table 1. Examples Of AR experiences with corresponding Display Device

Display	**Ref.**	**Short Description**
Desktop or Spatial	(Wojciechowski & Cellary, 2013)	An AR virtual lab.
	(Blum et al., 2012)	A mirror-like AR application for learning anatomy.
	(Sin & Zaman, 2009)	A system for visualizing the solar system.
Handheld or Mobile	(Tarng, Yu, Liou, & Liou, 2013)	A butterfly ecological system.
	(Liu & Tsai, 2013)	Location-based AR for helping students in English compositions.
	(Al-Khalifa & Al-Khalifa, 2012)	AR quizzes with Layar[4].
Headworn	(Arvanitis, Petrou, & Knight, 2009)	An AR system using an HMD[5] for simulating visits to the museum.
	(Juan & Beatrice, 2008)	A system with a TUI[6] for the learning of human body.
Projective	(Kerawalla, Luckin, Seljeflot, & Woolard, 2006)	An experience on the use of an AR tool depicting Earth and Sun relationships.

[4] Layar is an application that uses Location-based AR and Image-Recognition AR to display content. https://www.layar.com/
[5] Head Mounted Display
[6] Tangible User Interface

AR learning experiences include "metaphors" (Santos, Chen, et al., 2014) for displaying the content. These include the "glasses metaphor": those experiences that depict the content from the "eyes" of the user placing, thus, the real world in front of the user. For example the Garcia et al.'s tools for learning spatial abilities (Garcia Dominguez, Martin-Gutierez, Roca Gonzalez, & Mato Corredeaguas, 2012). Another metaphor is the "Mirror" metaphor, where user sees themselves and the real world is behind the user; examples of this are *Mirracle* (Blum et al., 2012) and *Gremlings in my Mirror* (H. F. Tobar-Muñoz et al., 2014).

As for the evaluation, researchers have studied:

- Ease of use (K.-E. Chang et al., 2014; Wagner, Schmalstieg, & Billinghurst, 2006; Wojciechowski & Cellary, 2013),
- Satisfaction (Y.-J. Y. Chang, Chen, & Huang, 2011; Garcia Dominguez et al., 2012; Ibáñez et al., 2014; Martín-Gutiérrez et al., 2010),
- Motivation (Campos & Pessanha, 2011; Kerawalla et al., 2006; Rosenbaum, Klopfer, & Perry, 2007; Salmi, Kaasinen, & Kallunki, 2012; Tarng et al., 2013)
- and, of course, Performance (Martín-Gutiérrez et al., 2010; Teng & Chen, 2012; Y.-S. Wang, Chen, Hong, & Tsai, 2013).

For evaluating the experiences, researchers have used methods like:

- Interviews (Jerabek, Prokysek, & Rambousek, 2013; Kerawalla et al., 2006; Klopfer & Sheldon, 2010; Klopfer & Squire, 2008; O'Shea et al., 2011; Shelton & Stevens, 2004; Wagner et al., 2006),
- Field observations (Arvanitis et al., 2009; Klopfer & Squire, 2008; Squire & Jan, 2007; Wojciechowski & Cellary, 2013)
- and Expert Reviews (Margetis, Koutlemanis, Zabulis, Antona, & Stephanidis, 2011).

All these works portrait how AR has passed from being called "in its infancy" (Kerawalla et al., 2006; Yuen et al., 2011) to be called "mature" (Santos, Chen, et al., 2014). Nonetheless, note also how authors have differences regarding the interpretation on the definition of AR. For example, some understand AR as a "concept" to leverage participatory learning experiences and simulations (Dunleavy et al., 2008; Rosenbaum et al., 2007; Squire & Jan, 2007). While others focus on the 3D experiences that afford novel educational experiences like (Dong, Behzadan, Chen, & Kamat, 2013; Tarng et al., 2013; Teng & Chen, 2012; Theng, Mei-Ling, Liu, & Cheok, 2007; Wojciechowski & Cellary, 2013) among many others. It is important to understand that this duality proposes different learning affordances and thus, more theoretical proposals are needed.

Another timely review on tendencies of the application of AR to education is the work of Bacca, Fabregat, Baldiris, Graf & Kinshuk (2014). They made a systematic review of the literature. Among their conclusions we can find that:

- The number of published studies about AR in education has progressively increased year by year specially during the last 4 years.
- Science and Humanities & Arts are the fields of education where AR has been applied the most.
- AR has been mostly applied in higher education.
- Marker-based AR is the most used type of AR.

Bacca and his colleagues classified the works according to the UNESCO's standard classification of education(UNESCO, 2012). They classified the works according to the "Field of Education" and "Target Group". They provided an analysis of the reported purposed of the application of AR to learning and the advantages and limitations of applying the technology to learning.

Among the advantages reported by Bacca's review we can find "Learning gains" in the 43.7% of the surveyed works and Motivation in the 31.25% of the works. Other advantages include Collaboration,

Low Cost, an increase in the learning as experience, just-in-time Information, Situated Learning and Student-Centered Learning among others.

Among the Limitations of the application of AR to learning, Bacca reported finding that authors who do not specify limitations account for a 68.75% of the works. Other limitations include the ergonomic factors like the difficulty to maintain the superimposed information, the students paying too much attention to the virtual information and the AR technology being intrusive among others.

In this thesis, a review was conducted on previous experiences on the use of AR for learning. The review looked for recent works (2007 and later) that showed experiences that applied AR in any of its forms aiming towards a learning objective. The review looked for experiences in the literature performing a documental research in the ISI Web of Science database. The database was queried for terms relevant to this research such as "Augmented reality", "Education", "Learning" and "training". The works obtained were reviewed; first the search looked for relevant titles and abstract. A second pass was done over the remaining works looking for works that described AR applications for learning. This resulted in 28 works that exemplify the application of AR for learning which were used to inspire this research and evidence the usefulness of AR in the learning realm.

From then, the review performed a survey on the remaining 28 works by classifying the works according to a typology defined inspired on (Azuma et al., 2001; Krevelen & Poelman, 2010; Normand, Servières, & Moreau, 2012). The typology classifies applications in three criteria: The Visual Display, the tracking and the Device Category.

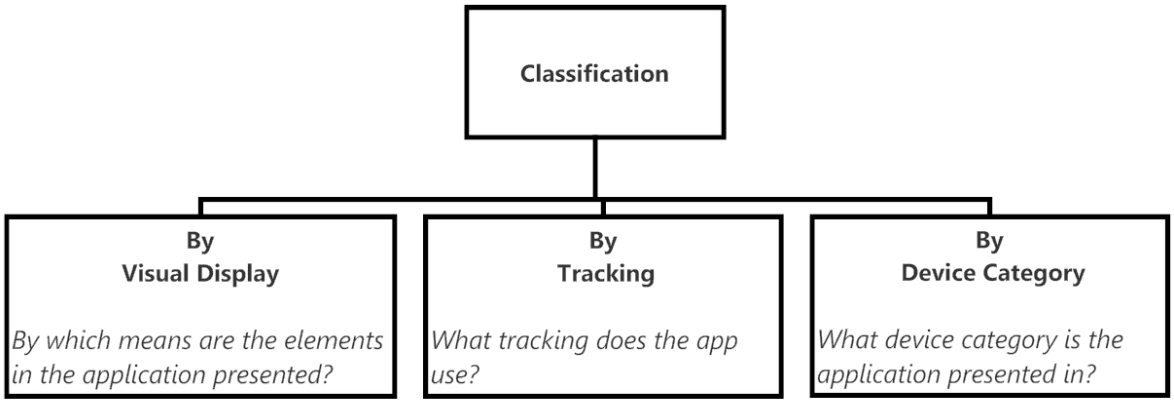


Figure 5. Classification of AR applications

The following figures depict the taxonomies used to classify works surveyed. The amount of works surveyed for each classification is mentioned in parenthesis. For the **Visual Display**, typology shown in Figure 6 was used. These are the same visual displays described by Krevelen & Poelman (2010) – Optical See-Through, Video See-Through and Spatial (Projective) - but the additional "GUI" Visual Display has been considered (shown gray in the figure) for applications that display elements in a regular GUI as it was not considered that applications such as *Environmental Detectives* (Klopfer & Squire, 2008) or *Outbreak @ MIT* (Rosenbaum et al., 2007) would fit in the other categories.

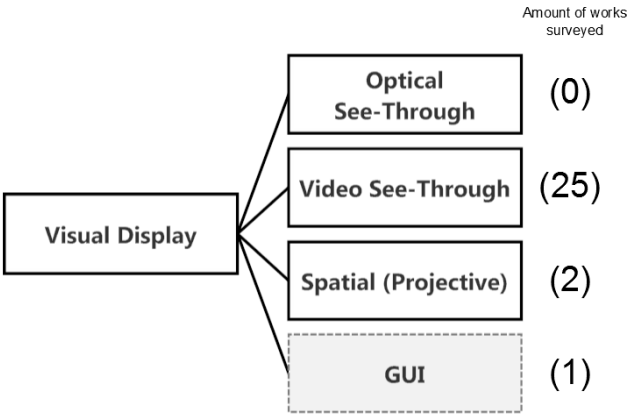


Figure 6. Typology used for the Visual Display criterion

The typology according to **Tracking** criterion was created based on the degrees of freedom proposed by Normand et al. (2012)

- 0D for basic scanning of markers such as QR-Codes
- 2D for tracking on 2 degrees of freedom, like in geographic maps
- 2D + $\boldsymbol{\theta}$ for tracking in 2 degrees plus a degree relative to the earth's magnetic north (for Layar-like applications)
- 6D for 6 degrees of freedom. Such as the use of AR markers, 3 axes are used for translation and 3 axes are used for rotation.

An additional category was added to Normand's proposal; the $\boldsymbol{\theta}$ + $\boldsymbol{\phi}$ category (shown in gray in the figure) which considers the orientation of the device, without a translation or a 2D tracking in a map, just like in the CONNECT project (Arvanitis et al., 2009). The following tree (Figure 7) depicts the typology, its leaves are the actual categories and their names are self-explanatory. Note that the sum of the amount of works surveyed is not 28 but 29. This is because a work (Teng & Chen, 2012) was classified as using both QR-Code Scan and Marker-based scan.

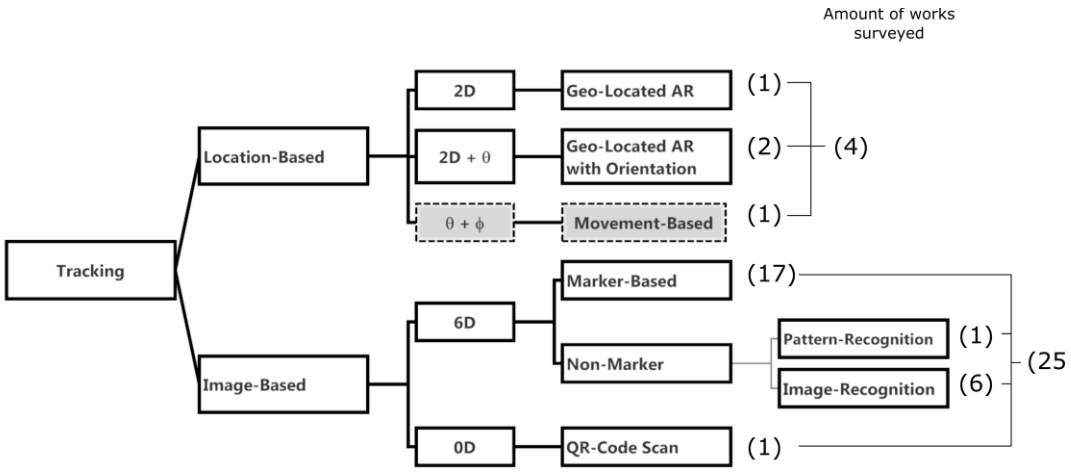


Figure 7. The typology used for the Tracking criterion in AR Experiences

And Finally, the **Device category** criterion was used in the same fashion as described by Azuma (Azuma et al., 2001). In Azuma's classification Spatial devices are those fixed in a point in space that track movable objects around; Headmounted devices, as its name suggests, are worn on the head, and Mobile devices include tablets and smartphones.

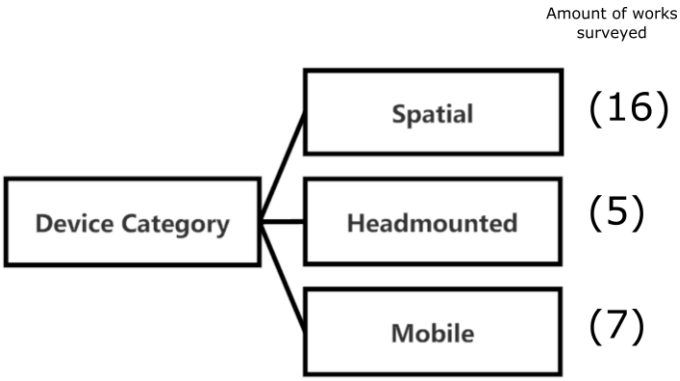


Figure 8. The typology used for the Device Category criterion

Each work found in the literature was surveyed and classified into the typology proposed. The final classification data is shown in Appendix A.

In these results, it can be seen that:

- In the Visual Display criterion, experiences displayed on Video-See-Through display are dominating.
- In the Tracking criterion, most experiences were using marker-based tracking.
- In the Device Category criterion, Spatial was the most used.

This may be due to the easier implementation of Video-Displayed applications which are easier to implement than, for example, Optical See-Through applications. Also as stable and easy-to-use tools do exist for marker-based implementations (for example the highly acclaimed ARToolkit, Metaio, NyARToolkit, among others) they appear in a major ratio than other tracking techniques. And finally, mobile devices are relatively new in comparison to standard desktop devices, and the latter were more reliable to run the algorithms and computer-vision methods due to their higher technical specifications. This is currently changing rapidly, because more and more mobile devices are appearing with astonishing specifications that find it easy to run such methods.

This thesis survey shows that the most **Targeted Group** is the primary education, followed by higher education and informal learning as depicted by Figure 9. The sum of the works classified is bigger than the works surveyed because some works classify in more than one category. For example (Cuendet, Bonnard, Do-Lenh, & Dillenbourg, 2013) was classified as applying for primary education and lower and upper secondary education. The actual classification can be found in Appendix A as well.

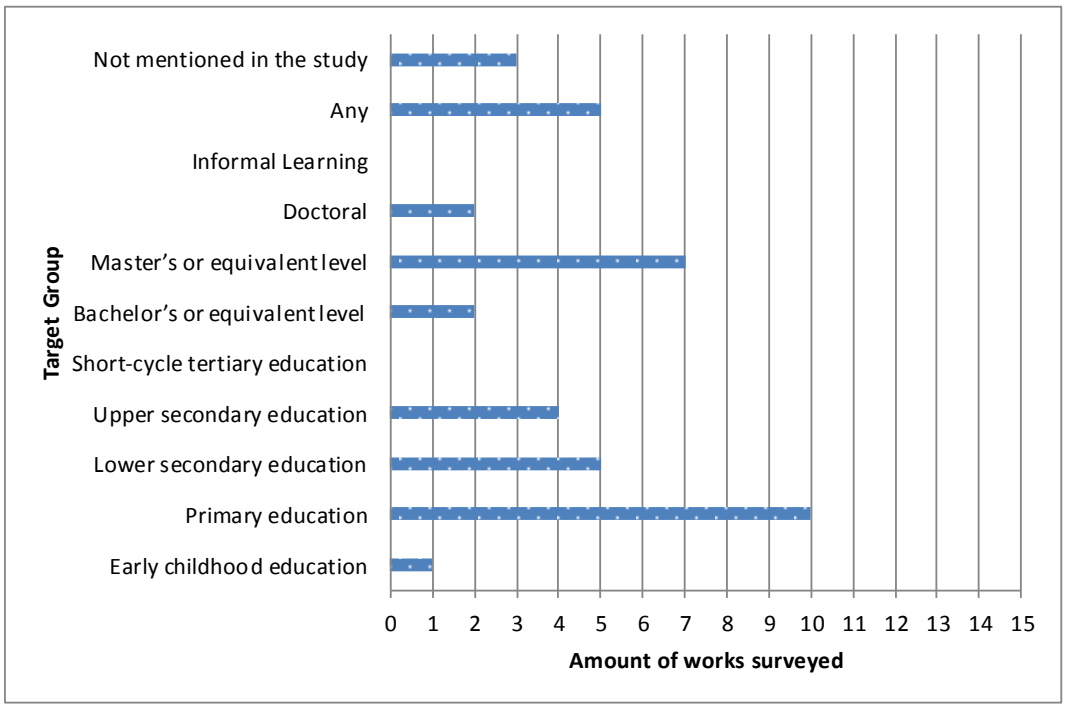


Figure 9. Distribution of the classified works by Target Group

This seems more coherent since AR is a relatively new technology and its didactical and experimental nature makes it easier to introduce in elementary education rather than higher education in the first trials. It is noteworthy that in the Master's (or equivalent) and Doctorate levels often the AR applications used by lesser levels are developed.

Regarding the **Educational Field** of the content in the AR experiences surveyed, most of the experiences were in the Science field. This result is in accordance with the work of Bacca et al. The distribution of works in educational fields is shown in Figure 10. As in the target group classification, the educational field classification also allowed more than one classification for a given work.

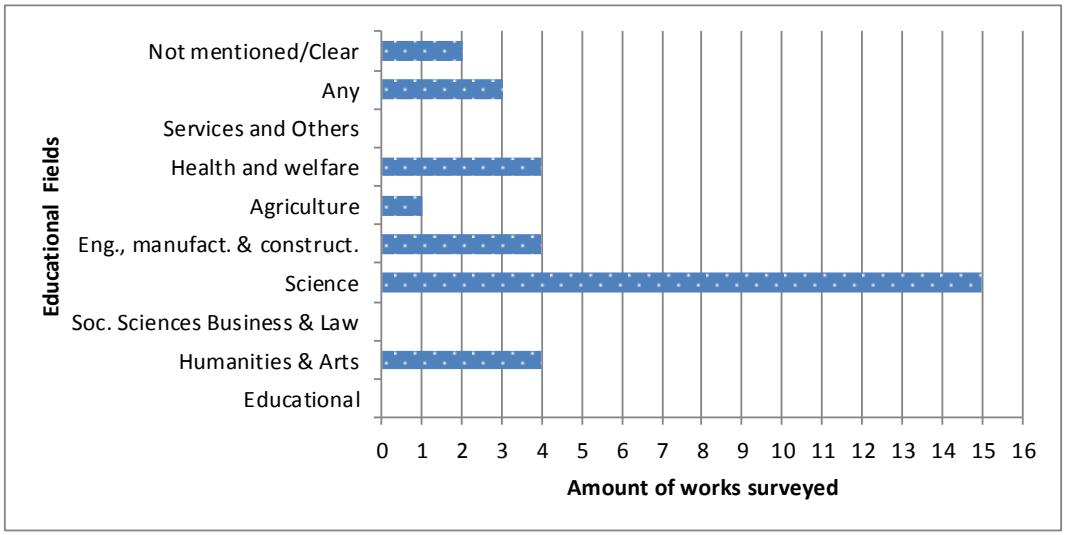


Figure 10. Educational Fields targeted by AR works reviewed

Since efforts to include AR technology in the classroom are often limited to short lab tests and few efforts have actually evidenced to be appropriated by teachers in in-the-wild scenarios (L. Prieto, Wen, Caballero, & Dillenbourg, 2014) and inclusion of teachers in the design of technologies for learning can foster the appropriation of said experiences by them, this study also focused on survey how the abovementioned experiences were developed and whether they included teachers in the design team. The survey highlighted that, although several studies did not stated clearly how they were developed, i.e. the **Design Team Approach**, most of the observed experiences were designed by developers/designers/programmers teams (See Figure 11).

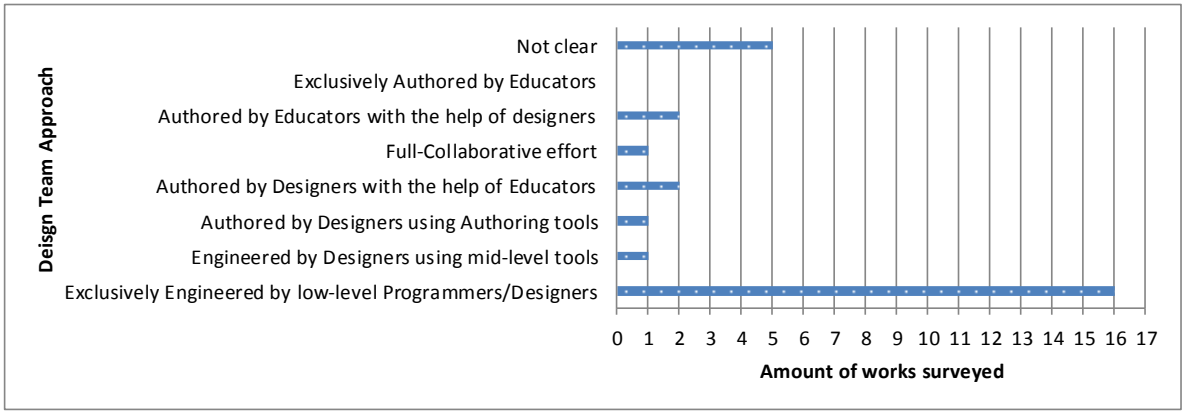


Figure 11. Amount of surveyed works related to Design Team Approach

This, perhaps has a bright side, it shows the compromise of teams for engineering new and innovative technologies for education. However, these studies did not showed significant contributions from the teachers. The participation of teachers in the process of creation of educational contents and technologies is important for leveraging better and effective formative processes. Teachers should be empowered to create their own experiences and have a less passive role. This is an important issue requiring attention from researchers.

2.1.2 AUTHORING AUGMENTED REALITY FOR LEARNING

Here we refer to the Authoring of Augmented Reality for Learning as the process conducted by non-programmers, or developers (often teachers) to create and choreograph some kind of educational experience involving the use of AR Technology in some fashion.

The Authoring of Augmented Reality has been proposed lately as a sub-type of the authoring of "Situated Multimedia" (Santos, Ty, et al., 2014). This is, to understand AR as multimedia elements (Text, Images and Sound) that are displayed in relation to the real environment and the authoring of it as the arrangement of those elements in a particular setting; constructing, thus, a new ARLE. For this and due to the impact ARLEs have had, some authors have been interested in developing instructor-oriented solutions that allow teachers to create learning contents and experiences using AR.

Some experiences were reviewed that allowed teachers to create learning experiences in an effective way. Those experiences are listed in Table 2 to show the feasibility and advancement of these types of technologies. The table shows several previous experiences appearing in scientific literature where AR authoring appears.

The experiences are described using the classification on the Tracking, Visual Display and Device Category as discussed previously. The last column "How does it author" describes the process in which the user participates in order to include learning content using AR. In many cases the user is able to edit a "scene" in which they relate virtual content with some element (like a marker) to be recognized by the system.

Table 2. Relation of authoring experiences for education using AR

Name	Ref.	Authored Product Classification			How does it Author?
		Display	Tracking	Category	
ARIES	(Wojciechowski & Cellary, 2013)	Video	Marker-based	Spatial	The teacher edits a scene by using a set of classes and objects previously defined by a programmer with attributes and behaviors. This is following an Object-Oriented paradigm. The objects are then used during an AR-based learning activity. A possible complication with ARIES remains in that there is a need for a professional programmer to use the tool.
Immersive e-Learning System for English Learning	(Lim & Lee, 2013)	Video	Marker-based	Spatial	The teacher edits the scenes with a power-point like tool. The results show augmented information over markers that are used for learning English language. Nonetheless the outcome of the AR experience is very simple.
iaTAR	(G. A. Lee, Nelles, Billinghurst, & Kim, 2004)	Video	Marker-based	Spatial	The user relates real objects with virtual objects by means of their properties. The user can set the behavior of elements using "logic boxes". The authoring is done using the TUI (Tangible-User-Interface) markers, so the interaction is WYSIWYG.
Authoring Tool for Use in Examination	(M. J. Wang, Tseng, & Shen, 2010)	Video	Marker-based	Spatial	The teachers input the Yes/No Questions in a GUI-based tool which saves the questions in a txt-editable file. The students use a viewer to see the questions and select their choice with the finger. In this case, the tool only allows creating a simple quiz.
AR-based authoring tool for E-learning applications	(Jee, Lim, Youn, & Lee, 2011)	Video	Marker-based	Spatial	The user uses a tool for authoring AR e-Learning experiences with markers. The tool lets the user establish the relationships between the markers and the 3D models produced in other graphical tools. The tool also uses Lua programming language for scripting the behavior of the elements in the experience.
SpotAR/AR Scratch	(Radu & MacIntyre, 2009)	Video	Marker-based	Spatial	This is an authoring tool aimed for children under the Scratch[7] programming platform approach. Children author using programming blocks predefined in the system. The main drawback of SpotAR is that it really does not render anything in 3D; it mostly follows markers and renders 2D images in 2D space over them.
Zoo Burst	("ZooBurst," 2015)	Video	Marker-based	Spatial	The author can create stories that appear augmented in a predefined marker. As of January 2017, Zooburst is not working anymore.

[7] Scratch is an easy-to-use platform for children to program their own experiences. https://scratch.mit.edu/

Aumentaty	(Aumentaty, 2015)	Video	Marker-based	Spatial/Mobile	The author relates Imagery with AR markers. They work also with Virtual Reality and Google's cardboard. Aumentaty is limited to showing the virtual imagery. However it does not offer the option to create interaction with the content.
Simple Handheld Authoring Tool	(Santos, Ty, et al., 2014)	Video	Marker-based	Mobile	Teacher downloads an image and relates it to a marker. They can be handled with touch gestures.
PowerSpace	(Haringer & Regenbrecht, 2002)	Video	Marker-based	Headmounted	The user creates a PowerPoint presentation with a central element to be replaced by the real element and a set of slides displaying the information. The slides can be controlled with the input system.
AR-Room	(Park, 2011)	Video	Marker-based/ Movement-based	Headmounted	The user uses the system like an augmented room, and they can control the elements to include in a scene and their behavior using a state/event/action structure.
In- Place Sketching AR	(Hagbi, Grasset, Bergig, Billinghurst, & El-Sana, 2010)	Video	Marker-based (Sketch)	Any	The user draws a sketch already recognizable by the system's library. In this way the author (who can be a teacher or a student) can create scenarios in 3D. The main drawback is that the system may not perform adequately when recognizing the sketches.
ARLearn	(Open Universiteit, 2014)	Video	Geo-Located	Mobile	A tool suite for educators and learners supporting different phases and activities during a field trip. Learners can use the ARLearn app to explore and annotate the real world, while teacher can monitor their progress in real time.
AR Authoring using a dual display in a Web-browser	(Asai & Kobayashi, 2006)	Video	Image-Recognition (Japanese characters)	Spatial	The user creates a marker with Japanese characters and the system recognizes them and relates them to things (text, 3D models and images) in the server.
Marker-Less Tracking for Multi-layer Authoring in Video AR Books	(Kiyoung Kim, Park, & Woo, 2009)	Video	Image-Recognition	Spatial	The user creates several layers with Augmented content to embed into the pages of an AR-Book. The book's pages are recognized with a fast algorithm and it is tracked with another algorithm
ARIS	("ARIS," 2015)	GUI	QR-Code Scan	Mobile	Author creates visual games with text and images and related them to QR-Codes.
TaleBlazer	(MIT Step Lab, 2015)	GUI	Geo-Located	Mobile	Teachers can design gaming adventures using Location-based AR. The adventures are similar to those like *Alien Contact*, *Outbreak@MIT* and *Environmental detectives* (Klopfer & Squire, 2008; O'Shea et al., 2011; Rosenbaum et al., 2007)
AuthorAR	(Lucrecia, Cecilia, Patricia, & Sandra, 2013)	Not clear	Marker-based	Spatial	The teachers can author two different kinds of activities: exploration and phrase. The student is given a marker and they must complete the instructional activities.
Command Center	(Tache et al., 2012)	Not clear	Geo-Located	Headmounted	The user can create a previously defined map of a natural environment and they can observe the trainees in action. Useful in military training and situations.
ARLOS	(Santos, Yamamoto, Taketomi, Miyazaki, & Kato, 2013)	N/A	N/A	N/A	This is a paper discussing the authoring of AR experiences as Learning Objects (ARLOS).

2.1.3 CONCLUSION OF THIS SECTION:

AR has had lots of applications in learning scenarios and authors show different advantages and limitations of its use. Regarding the authoring of AR learning experiences, many of the authoring tools have been used directly by teachers in an effective way. However, in many cases there were complications and obstacles for an adequate authoring process for the teacher. For instance, in (Wojciechowski & Cellary, 2013) there is still a strong need for a programmer knowing XML to design the system's classes prior to the teacher scene authoring. This leads us to think that authoring tools are still being observed in the lab and more research is needed to strengthen them and make it easy-to-use, accessible, effective and efficient for the teaching job. Also, the process of creating AR experiences does need of a time and effort investment from the teacher, but they have the advantage of becoming a permanent and re-usable learning resource (Yuen et al., 2011), so this should be had in mind when proposing this approach to practicing teachers.

2.2 GAME-BASED LEARNING

The application of games to learning has received a growing attention in the last decade, as some reviews show. Tsai and Fan found GBL research has grown since 2006 and there exists a rapid increase in online GBL research in 2010 (Tsai & Fan, 2013). Hwang and Wu found that the number of research articles has significantly increased during the past 10 years (Hwang & Wu, 2012). There is a tendency in the literature to consider games as exceptional, mind-changing, effective tools in the classroom. In this sense, and given this thesis' intention to apply GBL learning principles, a literature review has been done concerning the application of digital games to learning.

GBL took a especial boom after Prensky's publications (Prensky, 2001a, 2001b, 2004). In (Prensky, 2001a) Prensky subtly defines GBL as the "marriage" between digital games and educational concept. This "subtle" definition has led to complications since it makes it difficult to know what is to be understood as "games" (Steinkuehler & Squire, 2014). For that, Steinkuehler and Squire propose a working definition of "videogame for learning" based on the definition of Klopfer, Osterweil and Salen (Klopfer et al., 2009):

> *A voluntary activity structured by rules, with a defined outcome (e.g., winning/ losing) or other quantifiable feedback (e.g., points) that facilitates reliable comparisons of in-player performances…[that] target the acquisition of knowledge as its own end and foster habits of mind and understanding that are generally useful or useful within an academic context. Learning Games may be associated with formal educational environments (schools and universities, online or off), places of informal learning (e.g., museums), or self-learners interested acquiring new knowledge or understanding.*

Several theorists have argued about its advantages like helping with literacy skills (Squire & Jan, 2007); improving learning outcomes and learning session effectiveness (Merchant et al., 2014); games motivate, help to learn from failure, encourage competition and collaboration (Klopfer et al., 2009); games are interactive, customizable, problem-based and based on the user's expertise (Gee, 2007). Of course, games as any other learning medium are strongly dependent on their design and content implementation. However, recent works using empirical evidence can be found defending the power and potential of games, being used for several fields, like math (Hung, Huang, & Hwang, 2014), spatial cognition (Shute, Ventura, & Ke, 2014) and many others.

Games for Learning have been applied to many subjects and disciplines. As shown by evidence compelled by Hainey, Connolly, Thomas, Boyle, Wilson and Razak (2016), GBL has seen applications mostly in Mathematics, Language and Science, but it has been applied to other subjects too. Also, the same work compiles evidence of the behavioral outcomes of GBL that include: Affective and

motivational aspects, behavioral change, knowledge acquisition and content understanding, perception and cognition, and social and soft skills.

Games offer useful affordances and properties that are good for learning (Gee, 2009). In this context, an affordance is understood as *a feature of the world* (real or virtual) that will allow for a certain action to be taken (Gee, 2009); and moreover, games are especially good at matching these affordances with their actions and thus, work effectively with what Gee (Gee, 2009) calls *effectivity-affordance pairings.* These *effectivity-affordance pairings* are in the hearth of the games, they are naturally acknowledged and acquainted by players (especially digital natives[8]) and they make playing experiences useful for learning.

Among the most important theoretical contributions are:

- Properties of good Games for Learning (Gee, 2009). Among these properties Gee includes Identity, Interaction, Challenge and Consolidation, System Thinking, Problem-Solving and many more. These properties are basic and they must be understood and applied for a good design of games for learning.
- Games as designed experiences (Squire, 2006). Squire argues how educators profit from the understanding of games as designed experiences for learning. And how educators should plan experiences considering the game design constraints and the players' intentions.
- Games as "Exploratory Learning" (de Freitas & Neumann, 2009). The "Exploratory Learning Model" (Figure 12) is a learning theory based on the Kolb's Learning Cycle; it proposes a set of phases (elements of the model) for learning in virtual environments: Experience, Exploration, Reflection, Forming abstract concepts and Testing, following a cycle like this:

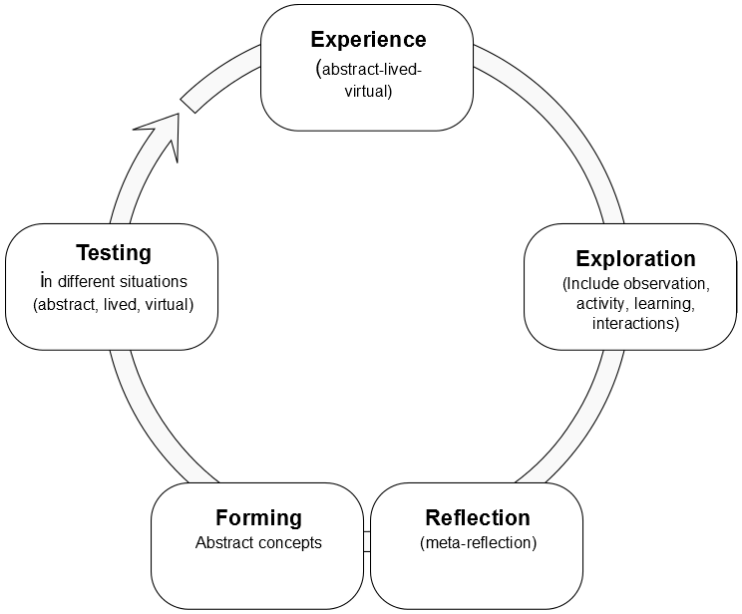


Figure 12. The "Exploratory Learning Model" (de Freitas & Neumann, 2009)

The same main author had already proposed how to evaluate Exploratory Learning in (de Freitas & Oliver, 2006) based on the highly acknowledged Kolb's theory of experiential learning (Kolb, 1984). In

[8] A digital native is a person born in the digital era: most youngsters nowadays and some adults (Prensky, 2001b)

this approach, de Freitas proposes a table with questions to answer while evaluating a game design for learning.

From a more technical perspective some researchers have studied, assessed, observed and theorized on how games can be integrated in Virtual Learning Environments (VLEs) (del Blanco et al., 2012; del Blanco, Marchiori, Torrente, Martinez-Ortiz, & Fernandez-Manjon, 2013; Tornero, Torrente, Moreno-Ger, & Fernandez Manjon, 2010; Torrente, Lavin Mera, Moreno-Ger, & Fernandez-Manjon, 2009; Torrente, Moreno-Ger, Fernandez-Manjon, & Luis Sierra, 2008; Torrente, Moreno-ger, Martínez-ortiz, & Fernandez-manjon, 2009). They have studied and argued that teachers can easily pack games accessible from a Learning Management System (LMS). This is mainly, since LMS currently are highly used for e-Learning and TEL, and these authors approaches are useful ways to deploy games for learning without impacting the process of learning design (conducted by teachers).

Torrente and his team (Torrente, Moreno-ger, et al., 2009) have proposed games for learning as Learning Objects (LOs), so they can be packaged and tagged using various already existing standards as for example standards for tagging like the widely used IEEE LOM; standards for content packaging like LO: IMS-CP; standards for communication among LOs like IEEE 1484 specification family, IMS-SSP and SCORM (del Blanco et al., 2013). In this same line, these authors have proposed a workflow for reusing successful game learning experiences as LOs. This workflow starts from the lesson development planned and executed by the teacher or learning design team, followed by the execution of the lesson, that, if results successful, is assessed and stored in a community repository for other teachers to carry on similar processes (Figure 13).

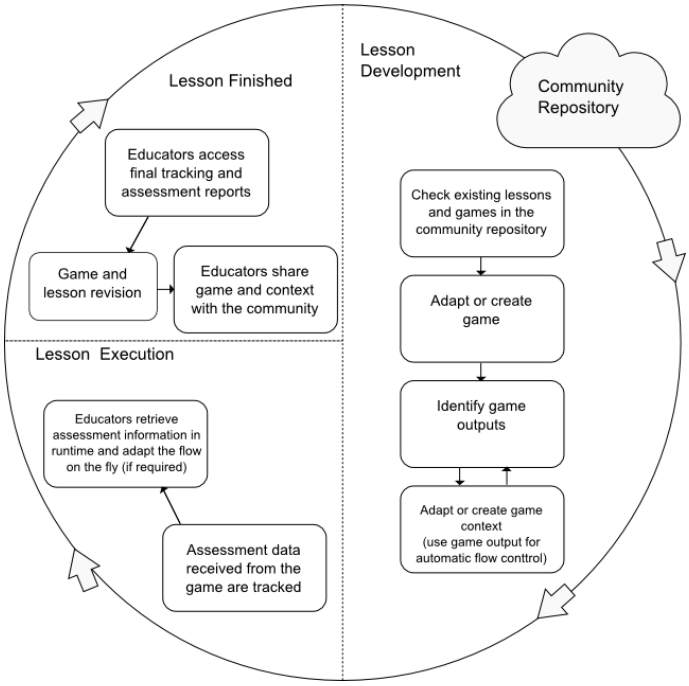


Figure 13. Workflow for learning integration in the Learning Flow (del Blanco et al., 2012)

Squire (2011a) and more recently Steinkuehler & Squire (2014) have proposed two interesting debates about the future of Games for Learning and the functions game have when supporting educational processes.

On one hand, Squire (2011a) proposes that the new educational games that succeed in this era won't be just "games" but learning systems that span home, school and other interests. This renders games to be novel educational contents affording new experiences and better learning; hence, game designers

should take that into account. Nonetheless, he argues that, for in order to achieve that, educational developers must satisfy current needs like: *Good market researches, Models and best practices for game development, and Resources for new business models.*

On the other hand, Steinkuehler and Squire (Steinkuehler & Squire, 2014) propose what educational roles games can have depending on their functions and uses; classifying them in:

- Games as content: When games are used to transmit knowledge or leverage skills.
- Games as bait: When games are used to promote thinking and learning in school settings.
- Games as architectures for engagement: When games are used as "sites" for engaged learning, this is, through motivation.
- Games as assessment: When games are used to assess students.

Given the rising popularity of GBL as a pedagogical method for learning, researchers have proposed models, frameworks and guidelines that help designers, teachers and other creative actors when designing games for learning. It is worth mentioning that there is not one single approach to models and frameworks because different approaches consider different aspects, such as immersion, social aspects, content-delivery aspects, and so on. In this review some models were analyzed and among these notable exampled include ATMSG, a model based on the Activity-Theory for proposing and analyzing games (Carvalho et al., 2015), the GREM model if users plan to create a game based on scenarios, elements and rules (Zarraonandia, Diaz, Aedo, & Ruiz, 2014), Marchiori et al.'s metaphor for narrative games (Marchiori et al., 2012), Social Games models like Cosmodel (H. Tobar-Muñoz, Lemos, & Niño, 2011) or the six-facets model as explained above (Marne, Wisdom, Huynh-Kim-Bang, & Labat, 2012).

GBL researchers have shown lots of experiences, features and advantages of games in the learning process On the downside, there are still complications about their application and effectiveness or efficiency (compared to more traditional methods) due to important obstacles like budget and time limits in educational systems that are far too smaller than budgets in commercial contexts (Klopfer et al., 2009; Marfisi-Schottman, George, & Tarpin-Bernard, 2010; Mehm, Goebel, & Steinmetz, 2011; Squire, 2011a; Tornero et al., 2010; Torrente, Lavin Mera, et al., 2009; Torrente et al., 2008). Another obstacle is the involvement, training and motivation of teachers for applying GBL; as it is the technological support they must have for an effective application of games in the classroom. These are still important open-issues to tackle.

2.2.1 AUTHORING GAME-BASED LEARNING

As in AR (and any other technology enhanced learning context) a particular interest has emerged to support the educator's work. So, in the case of GBL there are also tools and studies that allow the teacher to create and implement game experiences in educational processes.

A literature review was conducted which resulted in a set of authoring GBL experiences. These experiences were surveyed. Here, some of this experiences and conclusions are shown.

Apparently, one of the most notable GBL instructor-oriented authoring systems is <e-adventure>. It is cited as a case study in (del Blanco et al., 2012; Tornero et al., 2010; Torrente, Lavin Mera, et al., 2009; Torrente et al., 2008; Torrente, Moreno-ger, et al., 2009). It is an open source project ("eAdventure," 2014) that allows teachers to create point-and-click games with narrative graphical adventures including educational content. The project has proven to be versatile at the point that it has version for producing to mobile, 3D and a Nintendo DS (<m-Adventure>, <e-Adventure3D> and <e-Training DS>) (Tornero et al., 2010; Torrente, Lavin Mera, et al., 2009).

Studies regarding <e-Adventure> show how teachers have succeeded in the creation of educational scenarios. For example in (Tornero et al., 2010) depict how the authoring process is affordable within the time resources a teacher has.

Beyond the tool, <e-Adventure> main authors have proposed frameworks and practices that can be used with different platforms and LMSs as they propose the use of <e-Adventure> in compliance with e-learning standards like the Learning Object Model (del Blanco et al., 2012; Tornero et al., 2010).

More recently newer tools have appeared that allow the teacher to create educational interactive experiences. One of the most important right now is Scratch (https://scratch.mit.edu/) from MIT along with Gameblox (https://gameblox.org/). Scratch is mainly used by children. It can be used to program little animations and applications using a block-based approach. This way, authoring an application can be done by dragging and dropping blocks that represent code snippets and the like. Gameblox is similar to Scratch but it is intended to create games specifically and it is aimed to educators.

Other experiences were surveyed like U-GBL (J.-H. Chen, Wang, Chao, Shih, & Tang, 2008), a system that allows the creation of location-based educational experiences based on RFID tags, or ELG (Retalis, 2008), an environment or an authoring tool that allows teachers to create their own board digital games, allowing the creation of the assets, the educational activities, tasks and rules of the game; it has the option for tracking and assessment of students.

Del Blanco et al. (2012) contributed with a framework that depicts a way for introducing teachers into the use of learning games in the classroom. Authors also contribute with a workflow process to reuse these type of games edited. The case study uses <e-Adventure> as an example. The framework supports:

- Defining the goals of the learning process and assess the learning outcomes
- Adapt the learning process flow according to the outcomes measures
- Reuse of successful pedagogical approaches with games

In (Abdullah, Raja, Kamaruddin, Razak, & Yusoff, 2008) authors describe an authoring tool and a learning experience. The authoring tool is based in a framework that depicts a way to create educational content for games without the need to have programming skills or high computer knowledge. The process is meant to be no more difficult than the creation of Power-point slides. Later, authors show how this tool was used to create a simple game showing a fishing pool where kids "fish" letters in Jawi language.

Other commercial tools that allow the creation of games without being an expert in programming or computing exist. These include Alice3D (http://alice.org) which is aimed to be a tool to learn computer concepts, GameSalad (https://gamesalad.com/), GameMaker (http://www.yoyogames.com/studio) and KoduGameLab (http://www.kodugamelab.com/). These are not designed specifically to be used in learning contexts, but they ease the game creation job.

2.2.2 CONCLUSION OF THIS SECTION:

An interesting aspect of the reviewed works show how the authoring tools are concerned in bringing the content to an already existing game mechanic. Like in <e-adventure> which portraits the game content in touch and click screens, or the framework in (Abdullah et al., 2008) which, with the aim of making the authoring job easier, sacrifices an authentic creation of game rules. This can lead us to wonder whether games created simply by “grafting academic content onto existing game forms” is the right choice. This echoes with Klopfer, Osterweil and Salen (Klopfer et al., 2009) fifth design principle “Find the game in the content”. It may be interesting to find out until what extent are teachers able to author learning experiences with games without resorting to pre-existing game templates but rather finding the game that best suits the content at hand.

These are some highlights product of the observation on the experiences and the variables considered:

- The experiences reported that the target user of the tools is the teacher, with the exception of U-GBL that mentions a "Course-Designers team" which may or may not include professional programmers or technicians.
- Although, in the experiences, authors illustrated the approaches with exemplary case studies, it is rather viable that the tools can be adjusted to create other types of content.
- Most works produced 2D contents, with the obvious exception of <e-Adventure3D>
- The target hardware and devices were conventional PCs, Pocket PCs, Mobile devices and the particular case of Nintendo DS for <e-training DS>.
- It appears that efforts have not been focused in the creation of competitive or collaborative games. All the experiences were focused on single-user individual games, except for U-GBL that promotes collaborative participatory simulations that require teamwork.

The works on GBL authoring is still scarce, and thus most game –based learning affordances and particularities may not be profited to date. This is an open-issue and researchers should study what other features of games can be used for teachers when creating their own learning designs.

2.3 AUGMENTED REALITY GAME-BASED LEARNING

ARGBL or Augmented Reality Games for Learning, has been considered lately as a having potential for educational and pedagogical purposes. Such a claim can be supported by Schmitz, Klemke and Specht review (2012). They reviewed some papers using Games and Augmented Reality and concluded that, while it remains a young field, games have shown to impact motivation and knowledge gain when applied in educational activities. These authors propose, as future work, further research on the correlations on the design patterns and learning outcomes of ARGBL experiences. They claim this can be useful to motivate teachers to use such tools for teaching. ARGBL has also been considered in broader reviews like (Bitter & Corral, 2014; Radu, 2014) where they consider ARGBL experiences to be special because of the way they communicate and motivate students to achieve the learning and gaming goals. Yuen (Yuen et al., 2011) proposed AR games as one of his directions for applying AR to learning. Yuen claims that AR games present educators with the opportunity to utilize new highly visual and highly interactive forms of learning. Nonetheless, it is noteworthy how AR games inherit some of the detrimental aspects of the application of AR in the classroom, showing issued with attention tunneling, cognitive load and usability issues (Radu, 2014).

As expected, the works on ARGBL are few in comparison to those applying the technologies in separate ways. In this thesis a review on works including ARGBL experiences or applications was done. This review was made considering the works in the *Web of Knowledge* information service using the search term:

"Augmented Reality" AND (gam OR gamif*) AND (educat* OR instruct* OR learn*).*

That resulted in 83 entries. From those, the latest (2009 to present) refined to 57. Some iconic (but prior to 2009 works) were surveyed for their relevance to the field. Those included (Dunleavy et al., 2008; Klopfer & Squire, 2008; Rosenbaum et al., 2007)

After applying the following inclusion and exclusion criteria 27 works were analyzed

Inclusion criteria:

- Only works in English language, as looking in other languages can prove to be not optimal.
- The experience involves game or game-like elements.

- The experience involves AR elements according to flexible interpretation of Azuma's definition (Azuma, 2001). Much like in the same way Santos et al. apply it.
- The experience is in accordance with Steinkuehler and Squire's definition (Steinkuehler & Squire, 2014) as stated above (with some flexibilities).
- Work is from a journal or conference paper.
- The work describes a working prototype or experience.
- The experience's prototype offers some kind of educational content or skill-based practice.
- The work is publicly accessible.

Additionally, three commercial applications were included in the review (LogicalChoiceTech, 2011a, 2011b; PBSKids, 2012) as, despite not being portrayed in academic publications, show important efforts in mixing Augmented Reality and Games for Learning

The resulting references were surveyed and the variables used for the survey are explained in Table 3. The 30 works are detailed in Appendix B.

Table 3. Template defining the variables of ARGBL works reviewed

Reviewed work										
Name						**Year**				
Authors										
Publication										
Technologies used for the construction										
Classification	**Visual Display**	**GUI**		**Spatial**		**Video**		**Optical**		
	Device Category	**Mobile**		**HM**		**Spatial**		**N/A**		
	Tracking									
Content	**Description**									
	Target Group									
	Subject Matter									
Development Team										
Game Features	**Collaborative**		**Competitive**		**Individual**					
	Genre									
Evaluation	**Time of Treatment**		**Number of Sessions**		**Participants**					
	Time of Session		**Sample size**							
	Method									
	Results									
Feedback	**Role of the teacher**									
Recommended	**Frameworks, Theories, Tools**									

These variables were considered as a modification to the ones considered by Santos et al. (Santos, Chen, et al., 2014).

The classification of the applications is show in Figure 14, Figure 15, and Figure 16. As it can be seen in Figure 14, the *Visual Display* criterion is divided in Video See-Through, Spatial (Projective) and GUI display, but none applications were classified as using Optical See-Through display. It is natural, since Optical displays are often more expensive to develop. GUI displays are mostly Geo-Located because most early ARGBL works (Klopfer & Sheldon, 2010; Klopfer & Squire, 2008; Rosenbaum et al., 2007; Squire & Jan, 2007) were location-based, thus they displayed content in the form of information in a map (considered a GUI). Another use of GUI displays comes in the form of information retrieved from QR-Code scans (Bressler & Bodzin, 2013).

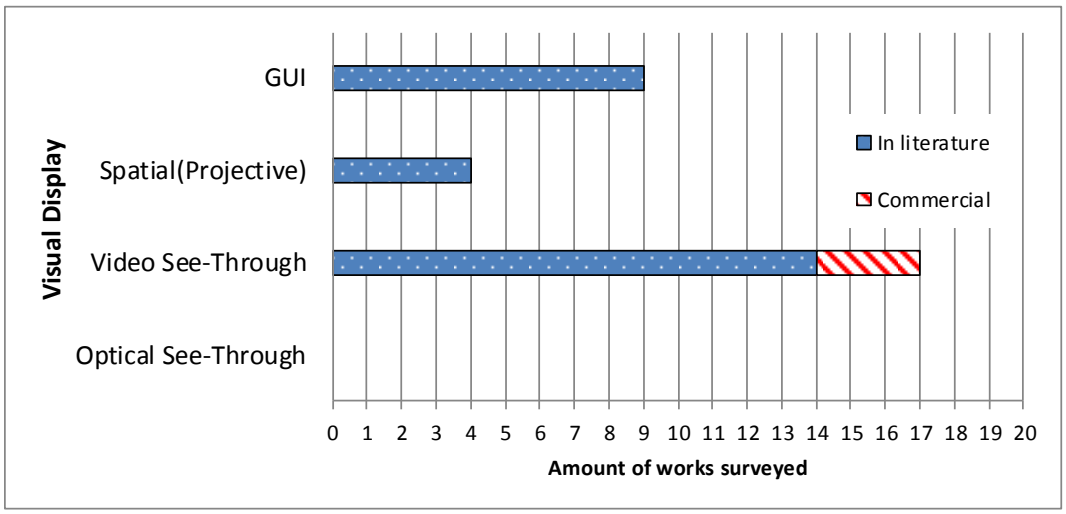


Figure 14. Classification of surveyed works according to the Visual Display criterion

Regarding *Device Category* (Figure 15), although mobile devices are relatively new in comparison to standard desktop devices, the current device market is flooded with devices capable to run the algorithms and computer-vision methods due to their higher technical specifications. Due to this, results of this review show how more and more applications are aimed to the mobile market. Observe, however, that part of the mobile applications belong to the 'Geo-Located' Tracking category while the rest belong to the 'Marker-Based' and 'QR-Code Scan' tracking categories. This reveals how some Tracking categories are tied to a particular Device Category like, as it can be seen in the table, 'Geo-Located' AR games that must be 'Mobile', because the aim of the designer is to guide students to live an outdoors experience. For example, in *Sick at South Beach* (Squire, 2010) students must take the role of scientist and investigators dealing with cases of intoxications in a real local beach. Also, while not all 'Marker-Based' experiences have to be 'Mobile', some of them run in mobile devices because they are easy to use for children and they allow the user to control their interactions while having the main medium of visualization (the mobile device) on their hands. Finally, 'QR-Code Scan' games follow an intention similar to 'Geo-Located' games, but often limit themselves to information displayed on the device that do not depend on external elements (location, orientation, etc.) For example, in *School Scene Investigators: The Case of the Stolen Score Sheets* (Bressler & Bodzin, 2013), much like in *Sick at South Beach,* students take roles to solve a mystery. However, in this game, students are limited to the QR-Codes (previously arranged by the teacher) that display information and character dialogues.

Regarding the 'Spatial' Device Category, the review found that this category is useful when teachers wish to use games as a central focus of attention, while allowing a hands-free control and manipulation of other elements (markers, toys, etc.). For example, *Ria's Math Play* (H. Lee, 2008) used as a focus a Board-Game with AR that displays information, characters and other virtual elements for learning Math; Campos and Pessanha (2011) configured a rig connected to a computer to show different animals in a matching game, this was meant to allow students to manipulate the game via Tangible-User Interfaces rather than a Graphical User Interface and Johnson and Sun (2013) who focused the attention on the human body by projecting, on one student's body, pictures of anatomical systems and structures while the student answers questions asked by the game, by pointing to the different parts of their body with the finger.

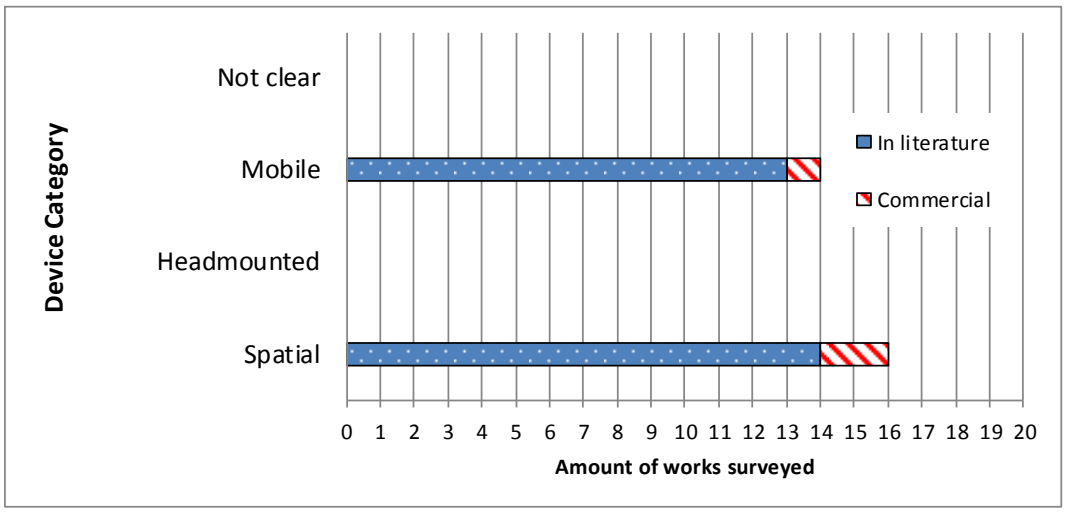


Figure 15. Classification of surveyed works according to the Device Category criterion

Notably, according to the *Tracking* classification, most ARGBL applications are Image-Based (Marker-Based and Image-Recognition). This may be due to the advent of Smartphones and Tablets capable of process video input and Image-Recognition algorithms that identify and track markers and images. Note that Marker-Based is the most prominent tracking technique used. And they come in both *Device Categories*: Spatial and Mobiles; while none application was classified as Headmounted. Again, Headmounted devices are often more expensive to develop and acquire, so this can explain this situation. Some of the Marker-Based ARGBL games surveyed use a webcam or a static camera rig to identify and track user's actions. For example Tobar-Muñoz, Baldiris and Fabregat (2014) used marker's to control characters in the game, while Chen, Ho and Lin (2015) used markers in a game board to perform interactions. From the mobile perspective, the applications found expect user's to move around markers and interact with elements virtually and physically. For example in *Fetch, Lunch, Rush* (PBSKids, 2012) player's select a set of cards to answer questions while Furió, Juan, Seguí, and Vivó's (2015) application show interactable simulations. These types of games and interactions can be found explained in (H. Tobar-Muñoz, Fabregat, & Baldiris, 2015).

The prominence of 'Marker-Based' applications may have its cause on the fact that stable and easy-to-use tools do exists for marker-based implementations (for example the highly acclaimed *ARToolkit*, *Metaio*, *NyARToolkit, Vuforia*, among others), so they appear in a major ratio than other tracking techniques like Geo-Location. Note that Geo-Located games like *Environmental Detectives* (Klopfer & Squire, 2008) and *Outbreak @ the Institute* (Rosenbaum et al., 2007) refer to applications of Location-Based AR that used specially designed software running on PDAs. Back when this early efforts were developed Mobile devices capabilities were not as the ones existing nowadays.

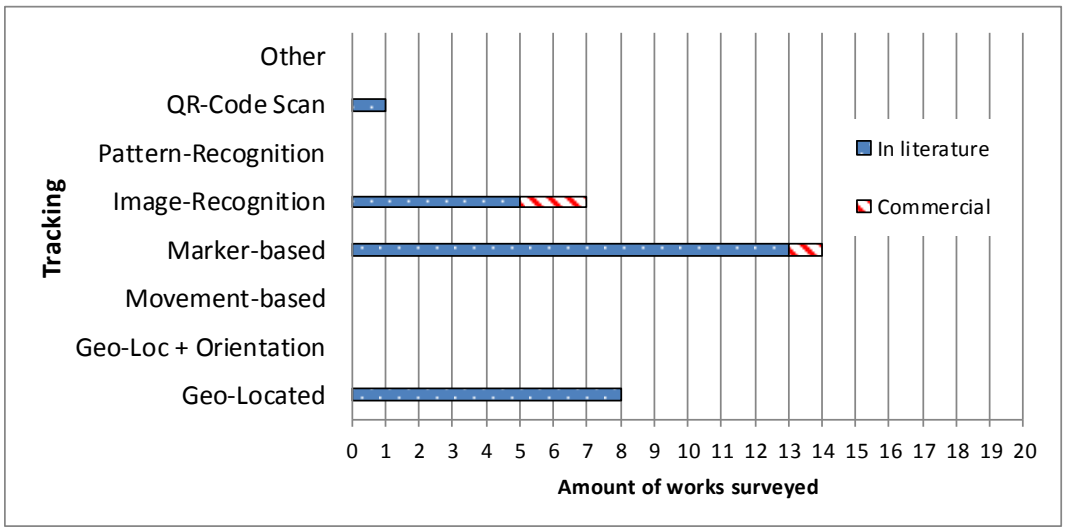


Figure 16. Classification of surveyed works according to the Tracking criterion

It is apparent, from these results, that the natural union between AR and GBL that can bring immersive and interactive worlds to the classroom has taken many forms. But, even more, results suggest that the trend is to develop games for learning that appeal to the learner by using the devices and tracking systems they have at hand in current mobile devices. As we can see from here, experiences are getting closer and closer to the public, being easily accessible and requiring only of easy-to-reach technologies like a mobile camera a projector and/or paper prints.

In the Target Group distribution (Figure 17) is shown how Primary Education and Early Childhood education are together the leading Target Groups among the surveyed applications. However, another Target Group is very often targeted in the applications surveyed: Informal Learning. In this review, the applications were classified as targeting Informal Learning according to the definition by UNESCO's ISCED. Although ISCED excludes Informal Learning from the Standard, it defines it as:

> *'…forms of learning that are intentional or deliberate, but are not institutionalized. It is consequently less organized and less structured than either formal or non-formal education. Informal learning may include learning activities that occur in the family, workplace, local community and daily life, on a self- directed, family-directed or socially-directed basis' (UNESCO, 2012)*

While informal Learning may not be considered as a "Target Group" strictly, it is indeed one form of application of ARGBL experiences that do not require an institutional setting. As a matter of fact, it is expected to be one of the scenarios of applications of Games for Learning as it is considered in the definition of a "videogame for learning" by Steinkuehler and Squire (Steinkuehler & Squire, 2014) cited in section 2.2.

The applications surveyed as targeting Informal Learning included those where its use does not depend on a formal environment (e.g. a classroom) but that can or it is recommended to be applied during free activities. These activities include playing by the sole entertainment purposes or playing in not-guided context (e.g. a museum). Examples of this are (Campos & Pessanha, 2011; Juan, Furió, Alem, Ashworth, & Cano, 2011; Klopfer & Sheldon, 2010; Ternier, Klemke, Kalz, & Specht, 2012). Examples also include the commercial applications (LogicalChoiceTech, 2011a, 2011b; PBSKids, 2012). The prominence of Informal Learning as a Target Group is natural because ARGBL applications are often designed to be used not necessarily in the classroom and their characteristics aim informal playful environments as those mentioned by UNESCO's ISCED such as family, community and the workplace. Also, applications classified as targeting Informal Learning, while may benefit from the participation of a teacher, often

are not-guided, self-guided or guided by family and other community members. Informal Learning was found more in the results of this review than in the similar review performed by Bacca (Bacca et al., 2014). This may be because as stated by (Stefan & Moldoveanu, 2013) unlike traditional AR applications meant to be used solely in the context of a formal environment, mobile AR games due to their interactive, playful, free, Self-Guided and Learner-Centered approach, blur the limit between formal and informal learning.

It is important to note that in this review some works were classified in two or more Target Groups. For example, Johnson & Sun's application uses a Kinect to learn anatomy (2013); The application is simple enough to the point that it can be used with different users and ages as shown in their paper.

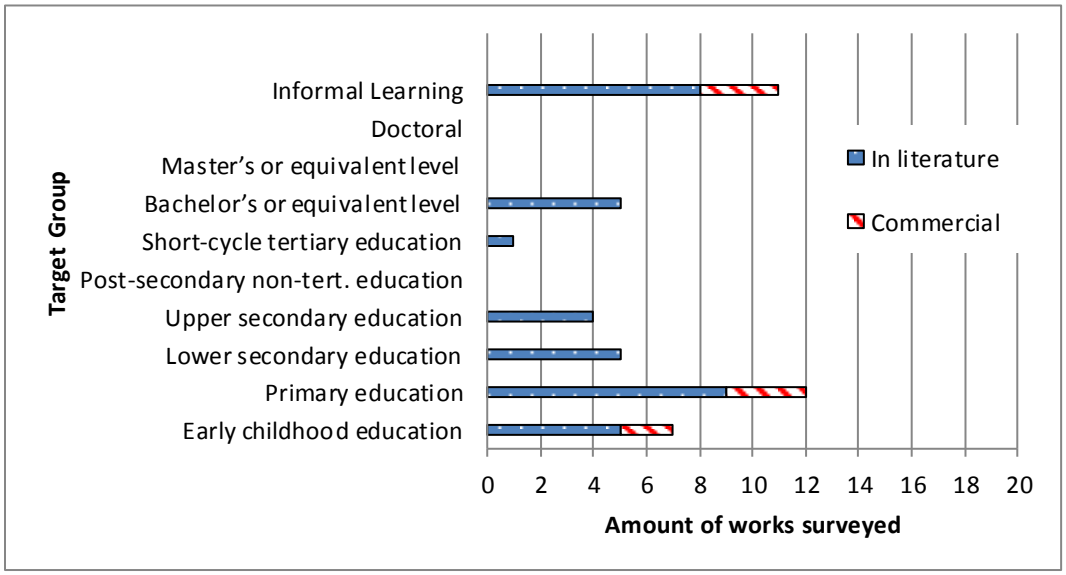


Figure 17. Distribution of the classified ARGBL works by Target Group

At first, it can be assumed that given the playful nature of games, most applications are developed to the early childhood and elementary education and then, higher educational settings are not targeted. However, this review was able to find that the Bachelor's or Equivalent Level Target Group was targeted by some ARGBL applications. For example, Guenaga et al.'s work (2014) show the application of an ARGBL game in the context of a laboratory to learn programming and robotics in a university and Ternier et al. (2012) led several university students using a Geo-Located AR game during an art appreciation course in Florence . Finally, interestingly enough, the work of Lin et al. (2011) was classified as targeted for short-cycle tertiary education. It depicts a game that shows an interactive simulator for learning about fish conservation which could be used in courses aimed to prepare skills for work in fishing-related fields.

It is noteworthy that none of the applications were classified as targeting Doctoral or Master Level education. This may be due to the highly specialized training that these groups require which could be out of the reach of games and AR.

As a final note regarding Target Group, this classification reveals that leaving aside Doctoral and Master levels, the ARGBL developments have targeted every level of education (Primary, Secondary and Tertiary) suggesting that while the virtual and interactive nature of games and AR could lead to think only in the youngest students (Early Childhood and Primary Education), current efforts show that older students (Secondary and Bachelor Education) appear to be a well-suited target population as well.

As Figure 18 shows the Science educational field keeps being the mostly targeted one, similarly to the application of AR experiences. However note how works like (Barreira et al., 2012; Dunleavy et al.,

2008; Ternier et al., 2012) count for the "Humanities & Arts" statistic in educational fields. Also, some applications were classified in the 'Services and Others' field; for example, the three applications of Yamabe and Nakajima (2013) which were aimed to present with playful training on playing poker, playing the drum and learning calligraphy.

From the first studies that united Augmented Reality technologies with games, the 'Science' educational field has been the most targeted (Klopfer & Sheldon, 2010; Rosenbaum et al., 2007; Squire, 2010). The Inquiry-Based nature of science renders this educational field as ideal for AR and GBL, because on one hand the explorative nature of AR allows students to discover, hypothesize and experiment on the virtual environments, while the game elements of the experience allow students to live their own experience by accepting, entering and performing in the rule-governed world of the playful environment. For example in games like *Mad City Mystery* (Squire & Jan, 2007) and *Environmental Detectives* (Klopfer & Squire, 2008) students were tasked with the discovery of a 'mystery' by means of hypotheses, experimentation, heuristics and logical thinking.

Other games that target 'Science' as the Educational Field were more aimed towards a particular learning objective such as the learning of Physical Concepts in Music (Gomes, Martins, Dias, & Guimaraes, 2014) Logical Thinking (H. Tobar-Muñoz, Baldiris, et al., 2014) the Food Chain (C.-H. Chen et al., 2015) or The Cycle of Water (Furió et al., 2015).

Nonetheless, while not prominently, other fields have been targeted such as Humanities and Arts during the art appreciation trip (Ternier et al., 2012) and Engineering with the Programming Skills game (Guenaga et al., 2014).

These results evidence that ARGBL can have a wide spectrum of applications regarding the educational field it aims. However, researchers and developers shall find a suitable filed in the natural sciences. Nonetheless, other educational fields may and should be targeted and researchers should observe for opportunities where learning objectives can be drawn and achieved using games with Augmented Reality

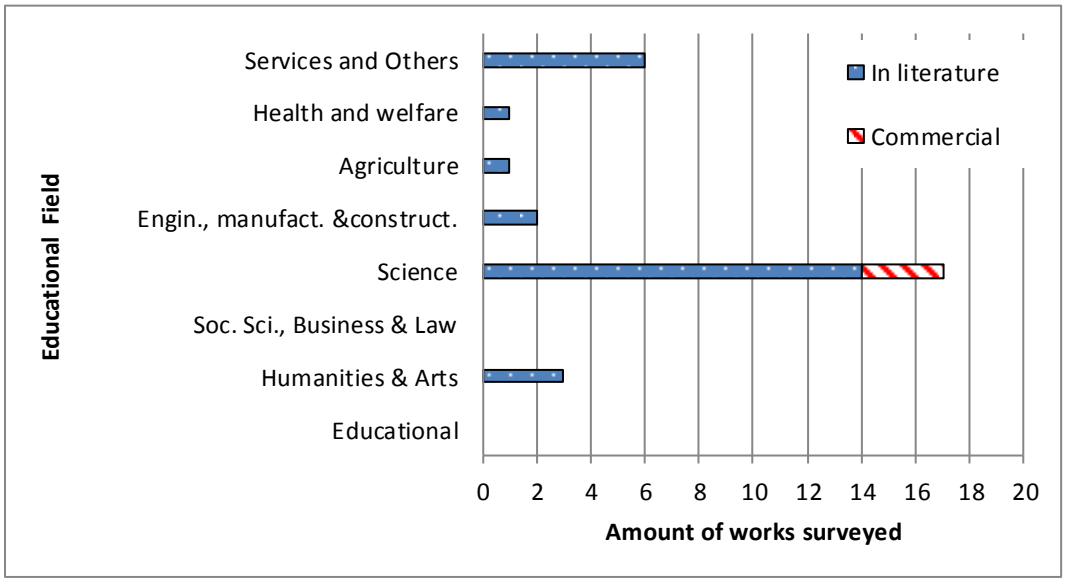


Figure 18. Educational Fields targeted by observed ARGBL experiences

As for the Design Team Approach (Figure 19) this review classified the applications according to the participation of teachers and designers (programmers, developers). It was found that most applications

surveyed were in fact developed by programmers/designers with minimum participation from teachers and with low-level tools (tools that require the user to be programming-savvy) such as *Unity3D®, Vuforia®* and *ARToolkit®.*

Among the ARGBL applications surveyed none were exclusively authored or created by teachers. It is noteworthy that there is a lack of authoring tools to create game experiences for learning involving AR, except perhaps for the recently-developed MR-GREP (Arenas, Zarraonandia, Díaz, & Aedo, 2015).

From the applications surveyed only a couple mentioned collaboration with teachers (Barreira et al., 2012; Campos & Pessanha, 2011). Others only mentioned gathering input from teachers(Bressler & Bodzin, 2013; Ternier et al., 2012). This is one of the main missing gaps found. Because if it is shown that ARGBL experiences are worth of using, this suggests that it is beneficial to include teachers and empower them to create experiences of their own.

From a more qualitative perspective is noteworthy how in many works studies reported non presence of the teacher or not consulted in the creation of the prototype or content. Also, in many of the experiences found (Carmen Juan, Carrizo, Abad, & Gimenez, 2011; Klopfer & Squire, 2008; Squire & Jan, 2007; Ternier et al., 2012) feedback was given in a debriefing session and not just-in-time. Or feedback was given by the system itself without the need of an expert (Yamabe & Nakajima, 2013)

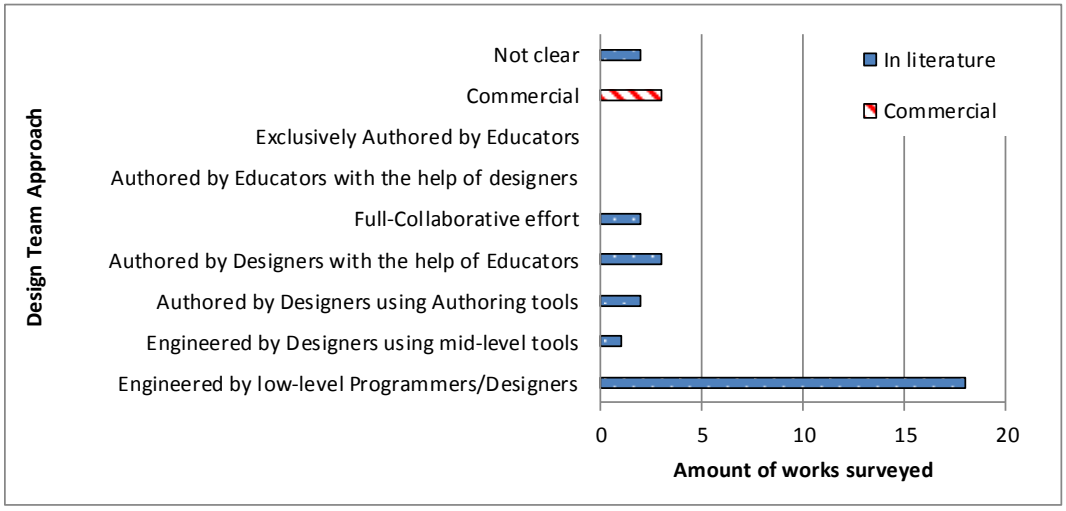


Figure 19. Amount of ARGBL surveyed works according to the design team

However, even though relationships between learners and teachers/instructors/ educational practitioners are being reconfigured (de Freitas & Neumann, 2009), teachers are not meant to disappear. On the contrary teachers must feel empowered and become an inspiring agent or a "choreographer" of the learning experience (de Freitas & Neumann, 2009; Squire, 2006). Thus, studies should consider the teacher more seriously and involve them in the process of content creation and execution of the learning experience. This said, it is interesting how this review found that there are two main ways AR games for learning are made: Authoring and "Design from scratch" (which is a way to call the direct design with no intermediate authoring tools). The review of the applications and experiences evidences how while authoring allows creators with no technical knowledge to portrait AR or GBL experiences, most of the time, those experiences will be simple compared to the ones created by professionals with design tools. Also, while most ARGBL experiences have been created by low-level programmers/designers using the appropriate tools, there are almost none full collaborative efforts that include teachers as active and creative actors in the process of creating an ARGBL experience. This renders an opportunity to create supporting technologies to help the designers and teachers to create ARGBL learning experiences. These tools may be by the authoring approach or methodological approaches to guide the design process.

2.4 CHAPTER'S CONCLUSION

In this chapter the literature review has been shown. It has been shown in terms of theoretical contributions and previous experiences regarding to the application of AR and GBL (apart and jointly).

In each section some open-issues have been considered and some conclusions and general observations have been asserted. Those assertions report the current knowledge on these aspects and the current missing gaps.

As for AR as technology, it can be said that it is mature enough as for working independently. So much that there are already plenty of AR commercial applications in the market and can be used in several devices. In the particular case of AR applied to education, several authors have labeled it as a powerful and effective tool for the improvement of students' performance. Nevertheless, although it has been called "mature" there are still some technological, system and social (especially regarding funding and resources) obstacles that must be addresses in order to achieve a wider acceptation and deployment of the technology. This thesis' study matches Bacca's (2014) assertion stating that most studies have been applied to the Science educational field (See Figure 10). Which is understandable since affordances for science like *Inquiry-based learning, conceptual change* and *conceptual understanding* are present in AR as stated in (Cheng & Tsai, 2012).

It has been shown how among technological support for educational processes are the authoring tools for teachers. Several applications and frameworks have been found dealing with this. But, there is still some need for research about their particular characteristics detailing effectiveness and efficiency.

Furthermore, GBL is consolidating as an important area. It is seen as a tool for a new education where students are the center of attention; a tool where students learn from their own experiences in a motivating and enjoyable environment. This paradigm has been shown as very mature at the point that many theorists have proposed models, properties, strategies, etc. characterizing the use of videogames in the classroom. Also, although there is still a debate on the efficacy of games, most experiences report benefits while other report contradictory and negative aspects (Steinkuehler & Squire, 2014).

In a similar fashion to authoring in AR, some technological experiences have been shown in GBL authoring. In particular, the <e-Adventure> platform and related works show how games can be included in the learning process and how their contents can be edited and used by teachers easily as it can be done with other types of media.

Finally it has been shown how the union of AR and games has been applied up until now and it can be seen how this union is still in need of exploration. Particularly, the work teachers need to do to support their work, from different points of view including the technology view.

Literature on the joint use of AR and GBL is scarce; this evidences a lack of conclusive research to establish whether the application of these technologies simultaneously is equally or better than the application of them apart. Also it becomes important to investigate how prepared are teachers to carry out such a process in the classroom. This research should consider technological and human aspects from the students and teachers perspectives since as claimed by Yuen (Yuen et al., 2011), some experiences using ARGBL approaches had disadvantages in educational settings, including: hardware and software problems, trouble managing students groups and cognitive overload on the students.

Some of the open-issued worth mentioning are:

- The impact of novelty effect. ARGBL experiences seem to be effective and they captivate students and increase motivation and engagement, but, are this due to the novelty of the technology and the eye-candy it proposes rather than due to inherent capabilities of ARGBL

technologies? Longitudinal researches are needed to observe the behavior of students beyond one or two sessions.

- How to make the professor an inspirer and not only an observer/conductor when applying ARGBL?
- How to make the educational content freely changeable by the professor?
- Most studies assert an improvement in learning or knowledge but few contrast that with standard tests.
- Are AR games more effective for learning outcomes than other kinds of media? (Including non-digital games and videogames without AR)
- How to empower the teacher to offer these types of contents without depending on a design team or programming crew?
- We excluded on purpose games aiming to function as assessment, but anyways there seem to be few of those. How to make new educational technologies be on the service of the assessment for teachers?
- Most AR games consulted seem to have been evaluated in short time. That may be due to budget constraints in the creation of games. However it differs from conventional gaming experiences of young people who tend to play and replay a game or play it once in a long time span. There should be experiences were players had the opportunity to live a game in a long time span and make observations about that process.
- AR Games for education are really focused on Marker-based TUI. This is important but there is still the question of what is the best interaction form an ARGBL for the sake of the learning and usability.
- Some authors claim that the collaboration is an educational affordance AR can provide, nonetheless, games found do not exploit this aspect.
- There is the need for a more general approach so new experiences and application not be so particular that can be used only in a limited set of contexts. Also to avoid the manufacturing of the educational content, but the authoring by teachers.
- The game genres in the AR games seem to be limited. What other genres could be used and how would they impact the learning outcomes and learning experience?
- There is a lack of "How to" (frameworks, design guidelines, criteria)
- What is the difference between using 2D GUIs versus 3D TUIs in an ARGBL experience?

With this state of art, the reader is expected to be situated in the epistemological context that literature reports regarding ARGBL. The reader can note how the aspects this thesis observes are still fields to explore. In particular, that there is a lack of methodological and technical approached to guide the process of designing ARGBL games and experiences that include both teachers and designers.

PART TWO: ARGBL EXPLORATORY SCENARIO

3 ARGBL IN THE CLASSROOM: EXPLORATORY SCENARIO

As it has been seen in the State of the Art part, the field of ARGBL is relatively new, and studies on it are scarce. In order to explore the implications of the use of ARGBL in the classroom an exploratory scenario was conducted. This scenario was used to explore the design, development, and evaluation of ARGBL experiences in the classroom which was done in order to evaluate and observe the implications and outcomes of the application of ARGBL experiences in the classroom. This also allowed a first encounter with teachers and it gained their interest in the creation of such experiences (as explained in chapter 5). Moreover the execution of this exploratory scenario allowed gaining insights into the needs for design and development of ARGBL experiences. Those insights were considered after in order to propose "Co-CreARGBL", the guiding method which is explained in chapter 4.

During the execution of this exploratory scenario a sub-type of Augmented Reality was chosen: Mobile Video-See-Through Image-Based AR as defined in previous chapters in the "Device Category", "Visual Display" and "Tracking" categories. This was done due to the availability of tools that, as shown in the previous chapter, there are plenty of tools that allow its development. A set of teachers (different to the ones belonging to the school were the evaluation of the scenario was done) helped as informers defining the learning objectives and general aspects of the game. The learning objective chosen was "To improve the reading skill in elementary school students". The scenario was used to measure learning outcomes and perform observations during the ARGBL playing and learning process. This helped to evaluate the implications of using ARGBL in the classroom.

Teachers proposed the learning objective because recently there has been a worldwide interest in reading comprehension due to the application of the PISA assessment. Only about 8% of students in OECD countries are top-performers in reading. Top-score countries with students in the top-level have

students with the right cognitive skills to "handle texts that are unfamiliar in either form or content and can conduct fine-grained analyses of texts" (OECD, 2014). However, Colombia (the country where we conducted this study) remains among the lowest scores. The consideration was also that ARGBL may enrich reading activities because while student focus on the reading that appears in a physical real world readable learning object (e.g. a book) their experience enhances by both: adding a virtual layer with interactable elements related to the reading (the AR ingredient) and a structured set of rules that add meaning and purpose to the activity (the Game ingredient).

AR has been employed in reading in the form of Augmented Books (Cheng & Tsai, 2012) and other forms of literacy activities which involve some type of virtual content which is often interactive. Proponents of AR activities for reading have identified the ways in which it can help students to read, such as allowing elements beyond 2D illustrations in the reading to be explored, providing innovative presentations of concepts and promoting active experimentation with them and a "sense of presence" which proposes a meaningful learning environment (Ramli & Zaman, 2009a, 2009b). Moreover, researchers in AR books have suggested that these may enrich the learning process by providing interactive experiences with the text and illustrations (Cheng & Tsai, 2014).

Some studies have investigated the use of AR for reading activities. For example, Ramli and Zaman (2009a, 2009b, 2011) devised courseware with AR to be used in reading activities tackling the problem of word recognition (rather than reading comprehension) for students with Down Syndrome. Meanwhile, Dünser (2008) proposed the use of interactive AR with readings on a computer and this was shown to benefit students who had problems reading traditional books, and Hornecker and Dünser (2009) studied the uses of physical "paddles" for interacting with the AR book.

With this in mind, the exploratory scenario was conducted to explore the students' behavior when a game using AR is applied in an educational environment for reading comprehension. With the help of some teachers, and under a Design-Based Research (DBR) approach (Barab & Squire, 2004; Collins, Beranek, & Newman, 1990). DBR was used as the general framework for designing the scenario and the design experiment (see section 3.2 below) conducted within a naturalistic environment. Nonetheless, to collect relevant data to compare students and to perform observations to identify the actions of the students, a mixed-methods approach was used (detailed later).

The ARGBL game is meant to be used with an accompanying reading. The game is aimed to children's reading comprehension rather than other aspects of the reading activity such as word identification (Ramli & Zaman, 2009b, 2011). The game has levels which present problems that are related to the reading test and requires students to comprehend this text to be able to resolve the problem, thus differing from previous studies, such as (Dünser, 2008), that only re-represent some aspects of the reading with virtual imagery.

With the game, this study investigated the following research questions:

RQ1. Do students benefit in terms of reading comprehension while using an ARGBL game? This includes two aspects:
  Aspect RQ1a: Performance on reading comprehension
  Aspect RQ1b: Motivation
RQ2. How the reading comprehension activity itself is enriched? i.e. how enriched is the activity in terms of collaboration, problem-solving skills, argumentation skills etc.

In order to answer the questions, a test was conducted in a real classroom performing both quantitative and qualitative observations. The results show that while results in reading comprehension using the game show no difference with results using more traditional approaches, children show motivated and interested in the activity and the activity is enriched by promoting problem solving, exploration and socialization behavior.

This chapter reports on the exploratory scenario and shows evidence of the advantages and disadvantages of ARGBL when used for reading comprehension in the classroom.

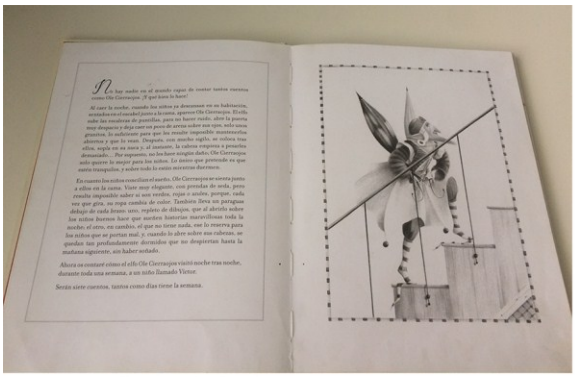
3.1 DESCRIPTION OF THE ARGBL GAME USED IN THE EXPLORATORY SCENARIO

The ARGBL game was created as an Augmented Book (Yuen et al., 2011). It uses a physical book with a printed reading as the Image-Based marker recognition. The book selected was a commercial book, a tale book by the name of "*El Pequeño Elfo Cierraojos*" based on the traditional tale of *Ole Lukøje* by H.C. Andersen (Andersen & Puybaret, 2014). The game is essentially a videogame whose elements are virtually superimposed over the illustrations of the book. The interaction is mainly through the device's touch screen and most elements react to the player's input.

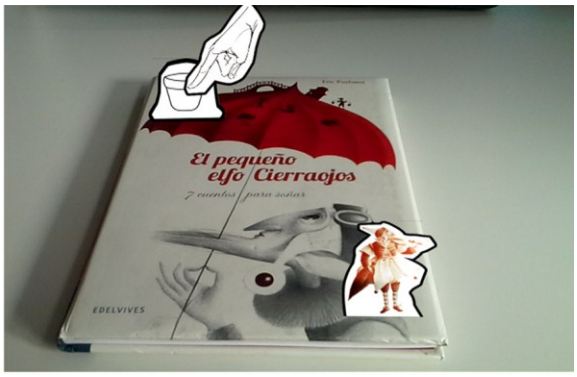
The game was called *"AR Ole Cierraojos"* and it was implemented for Android tablets and smartphones. The game was inspired by the traditional *pop-up books* that show some cardboard-made elements and imagery inside the pages. In the game, each page is an ARGBL game that uses the illustrations on the book as AR markers. Each game is based on a *reading comprehension question*: i.e. some kind of problem that the children have to solve in order to advance. The solution is not trivial, and it requires the child to read, comprehend, reflect on and/or infer by the accompanying text. For example, in the page 3 of the book the elf Ole (the main character) transforms the flowerpots into big trees with different decorations. In the game, the player has to transform the flowerpots in the room and then proceed to decorate a tree according to the description of the trees in the book. In this game, the player can use several decorations but only the same combination of decorations used by Ole in the book wins the game. The demo prototype comprised five different scenes, one for each of the first five pages, each with a different game. Figure 20 shows some scenes of the game in action. Table 4 shows the summary of the storyline and explanation of the games for each page in the book.

Table 4. Summary of the storylne and explanation of the games for each page in the book

Scene	Summary of the book page	Description of the game for the page
1	This is the Title Page	The scene shows a Tutorial scene where the player moves the main character the elf, using fingers and the touch screen and they learn how to use the elf's abilities by using GUI buttons and selecting the right object in the scene.
2	The book presents Ole the elf and its characteristics. It says the elf helps children sleep using magical sand. He also uses his different umbrellas according to the behavior of the child.	The player has to use the magical sand over children and make them sleep. After that, they have to assign the umbrellas correctly according to the displayed behavior of the kids shown in the game.
3	The elf transforms the flowerpots into big trees with different decorations.	The player has to transform the flowerpots in the room and then proceed to decorate a tree. In this game, the player can use several decorations but only the same combination of decorations used by Ole in the book wins the game.
4	Ole animates a school book and from it animated letters and numbers come alive. As some of them are miswritten, Ole makes them exercise until they are not crooked anymore.	The player has to choose the miswritten letters and use the "gym" power to help them workout.
5	Ole animates the furniture in the room. They have different behaviors. Specially the spittoon which is mad at everyone because they are spitting on it.	The player has to use magic on every piece of furniture and watch their reactions.

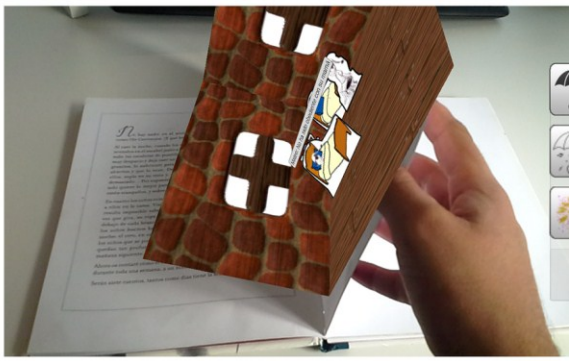


The book: Each page has an illustration.

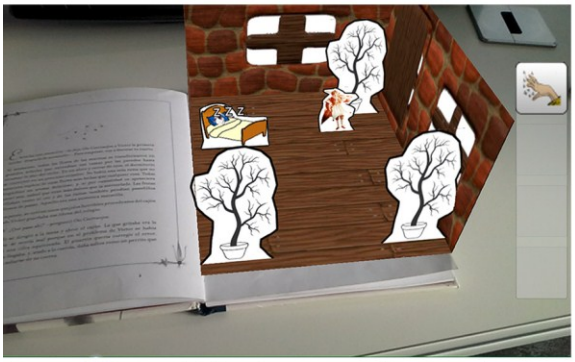


Scene 1: The player learns to play in the cover page.

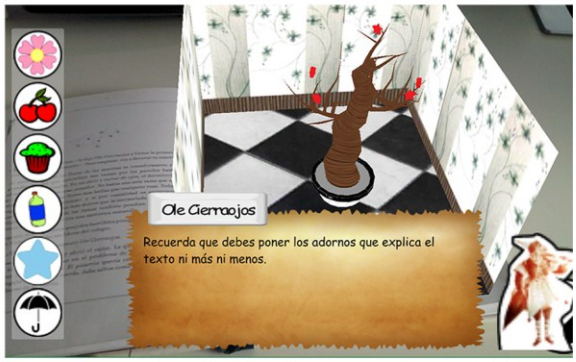
Scene 2: The player must put the children to sleep.



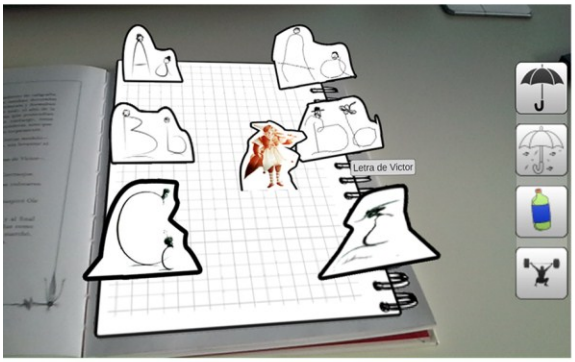
The scene moves with the page



Scene 3(first part): The player grows the plants into trees.



Scene 3(second part) - The player must decorate the tree



Scene 4 - The player helps the letters in trouble

Scene 5 - The player animates the furniture

Figure 20. The game "AR Ole Cierraojos" in action

As DBR is meant to be iterative (K.-C. Chen et al., 2006) the process of design and development passed through a set of iterations briefly discussed here:

- **Design:** A design team created the game. Teachers participated as informers by providing problems and ideas for the game. Brainstorming sessions were then conducted to achieve the main idea. Then, the game's early prototypes and concepts were tested.
- **Early iterations:** These were mostly play-testing prototypes within the design team. The main aspects to check included how the elements were going to be displayed in the augmented scene. Participants were asked if they felt comfortable and understood what the main objectives were. One of the most interesting feedbacks obtained was that people tended to point the text on the book in order to read it, maybe expecting something to "pop-out" in a similar way as the virtual content displayed on the illustrations. However, they figured out easily that the game was meant to be played with the device and the text was meant to be read normally.
- **Iterations with children:** Early prototypes were tested with children in a lab-environment. During this iteration children interacted with the game showing the main actions they would perform with it. Mainly, it was identified that children tend to perform *trial and error* when they explore the game and after realizing that they need to comprehend the reading, they resource to the book.
- **Play testing in a naturalistic environment 1:** A playtest was conducted with a set of 31 children in a classroom of an Elementary School in Popayán, Colombia in order to overview the game's main interactions. These observations were used to refine the game's mechanics and objectives.
- **Play testing in a naturalistic environment 2:** This iteration was conducted in an Elementary School in Popayán, Colombia with 51 students. It is the most heavily documented, and it is the one described here as the exploratory scenario.

3.2 DESIGN EXPERIMENT

In order to study the implications of the use of the ARGBL game in the classroom, a Design Experiment was conducted (A. L. Brown, 1992). A Design Experiment is an experiment where a particular learning innovation is tested. It includes engineering a particular form of learning (e.g. a game) and evaluating its shortcomings in a naturalistic setting (e.g. a classroom). After a Design Experiment is done, researchers conduct a retrospective analysis in order to develop theories that explain the observed insights (Barab & Squire, 2004; Cobb, Confrey, DiSessa, Lehrer, & Schauble, 2003). A Design Experiment was conducted with the use of the game as recommended by the DBR approach (The Design-Based Research Collective, 2003). The Design Experiment using *AR Ole Cierraojos* is described here.

The main conjecture of the experiment was that "using an ARGBL game for a reading comprehension activity, benefits children in terms of performance and motivation". On one side this conjecture states that children will be prone to play the game, and that will prompt the students to solve a problem by the very nature of the game. Such a problem requires the child to pay attention, read and comprehend the text. This was believed based on the fact that games are problems and they provide a meaningful framework for offering problems to students (Kiili, 2005). On the other hand, the AR aspect of the game will appeal to the children and will provide a center of attention, creating an authentic learning environment engaging, motivating and stimulating the students (Yuen et al., 2011). Also it was believed that the experience would be enriched based on the consideration that AR promotes collaboration among students and communication with instructors (Diegmann et al., 2015; Radu, 2014; Yuen et al., 2011).

Note that the term "conjecture" is being used as it presents the design experiment in terms of Sandoval's *conjecture maps* (Sandoval, 2004, 2014). Conjecture Maps are, in Sandoval's words: *"a mean of specifying theoretically salient features of a learning environment design and mapping out how they are*

predicted to work together to produce desired outcomes". Thus, a Conjecture Map is used here (Figure 21). The Conjecture Map depicts the salient features of the experiment. It also shows the Mediating Processes that were expected to occur in order to achieve the Intervention Outcomes.

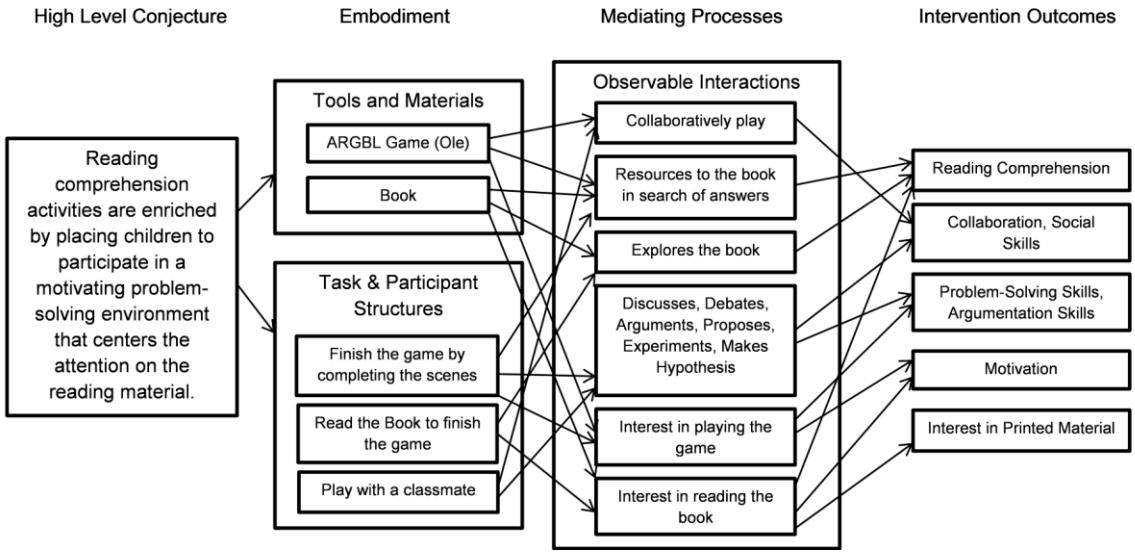


Figure 21. Conjecture Map of the Design Experiment

Observe the relationships in the Conjecture map. It shows that the general "High Level Conjecture" gets embodied through the "Tools/Materials" and "Tasks & Participants Structures" blocks (As depicted in the "Embodiment" column). These blocks depict how the design includes the tools, materials and the tasks that participants (students and teachers) are expected to do while in the experiment. Observe how a general idea —the "High Level Conjecture"— leads to the designed elements of the experiment and that some processes are expected to occur and be observable (depicted in the "Mediating Processes block"). For example, the students participating by reading, playing, discussing, collaborating and so on. Based on these, in the Intervention Outcomes panel of the map it is shown the expected intervention outcomes including reading comprehension, collaboration, social skills, problem-solving skills, motivation, interest in the printed material and other aspects related to the enriching of the activity and the development of further skills.

PARTICIPANTS

Participants on the design experiment were 51 students in grades 3rd to 6th from an elementary Colombian school. Researchers were authorized by the parents or legal tutors and the school headmaster to perform the experiment, meet the students and carry on the observations during two weeks. Students were 8 – 12 years old (M = 9.61; SD = 1.32) 43.1% girls and 56.9% boys. Among the participants, 16 (31.4%) were from 3rd grade, 9 (17.6%) from 4th grade, 15 (29.4%) from 5th grade and 11 (21.6%) from 6th grade.

Prior to the application of the game interviews were conducted with the students. This was done in order to get to know the students deeper. Students in this school are from mid-to-high income households. They tend to be from families with enough wealth to support their education. During the interviews, 11 students declared they like to read. Students who reported they like to read tend to live in a context where they can obtain printed materials easily. Some of them reported having a library at home or going to public and in-school libraries. In three cases, students declared not liking reading at all and only reading because they felt obligated by teachers or parents. Nonetheless, in the big scope, students declared they use to read and they do not feel obligated to do so. Students said they liked reading for various reasons, mainly for leisure and learning.

Regarding gaming, children showed very excited during the interviews when told they were going to play. Almost all of them said they loved videogames. These boys and girls seem to live in a technology filled context. They said they play in lots of platforms owning videogame consoles, tablets and PC's. They use their parents' or relatives' smartphones to play *Facebook Games, Mobile games* and *Friv games*. Only in one case, a boy said he did not like to play videogames, but because he did not feel he was good at playing, not because they were not a fun activity. This boy was the one who showed liking reading the most, and being an assiduous reader based on the deep explanations and comments on his latest lectures including *Coelho, Neruda* and *Homer.*

It was observed from the interviews and by meeting the children, that videogames are a part of their lives. It is even a social aspect. We observed them playing on smartphones and tablets during recess; there is a current interest in games like *Five Nights at Freddy's(FNAF)* (Cawthon, 2014)*, Geometry Wars* (Cakebread, 2014) and *Minecraft* (Persson & Bergensten, 2014). They seemed very social about these games, they were observed commenting on them, exchanging strategies and recipes on *Minecraft* and there is even a *CreepyPasta* (a viral internet horror story) about the origin of the story in *FNAF* (a horror game). This echoes with Squire's (2011b) claim and understanding of videogames as part of the participatory generation which is very social. Also, none of the participants knew nor had experienced AR, so it is a novelty to them.

In the experiment, an experimental group and a control group were formed to perform a comparative study. Participants were grouped in couples at random. This was because, as previous studies have noted (Dünser & Hornecker, 2007; Hornecker & Dünser, 2009), the use of the AR book may benefit from the participation with peers. Some couples were assigned randomly to the experimental group (i.e. the ones who would play the game) and other couples were assigned to the control group (i.e. the ones who would only read the book). Although there is debate in using a control group in a study like this, this was done to better observe the differences between using the game and not using it. Moreover, students in the control group were allowed to use the game after the data collection.

Information equivalence (Larkin & Simon, 1987) can be considered achieved because in both groups the main learning object's information (the book) is present in both settings. This is particularly interesting because as Sommerauer and Müller (2014) discuss, *Informational Equivalence* is often difficult to achieve due to the differences in representations using AR and traditional learning objects. In Figure 22 two experimental groups are shown interacting with the tablet and the book and two control groups are shown reading the book. The situation was videotaped and the students were helped if they needed any help on technical aspects. Their teacher was present during the class as is natural and three researchers helped with the process by solving technical questions and helping students when needed. During the students' interaction with the game, one researcher was in charge of asking questions to the students in order to gain insights into their feeling and general experience.

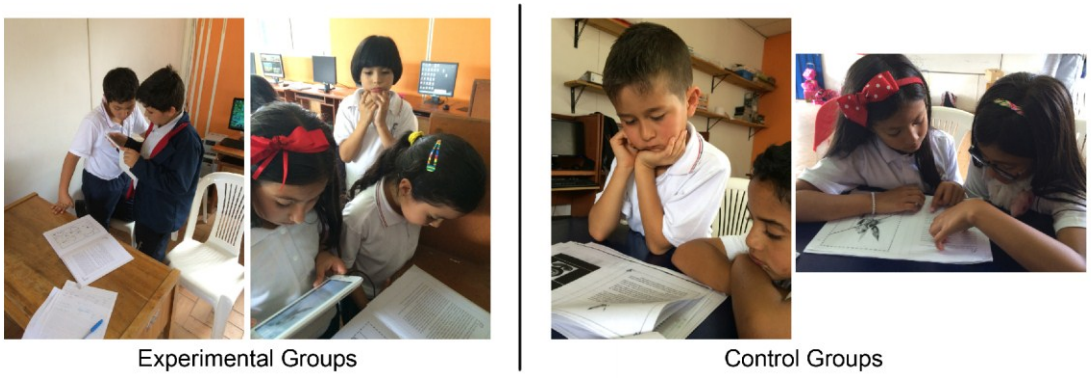


Figure 22. Students participating on the experience

3.3 DATA COLLECTION IN THE DESIGN EXPERIMENT

The design experiment allowed the collection of important data needed for the retrospective analysis and the consequent observations of the process. The design experiment results were observed from a quantitative and a qualitative perspective. This approach allowed observing the learning outcomes, motivation outcomes and other aspects when students interacted with the ARGBL game. In this section, the data collection is explained.

3.3.1 QUANTITATIVE DATA COLLECTION AND ANALYSIS

For the reading comprehension performance measurements defined previously (research question aspect RQ1a) a questionnaire was designed (*alpha* = 0.625) with the help of a reading comprehension expert (see Table 5). The questionnaire was validated with the help of a second expert who works as a Spanish teacher and whose subject includes reading comprehension. All of the questions refer to the accompanying reading not to the game. Thus, as *Informational equivalence* is guaranteed students should be able to answer the questions regardless of whether they used the game or not. The questionnaire has eight questions divided into two sections; students were not conscious of these sections nor does the questionnaire explain them. The first section (called S1) has four questions meant to ask about situations that the game deals somehow (i.e. the game portrays elements related to the question). For example, the game relates to question in the mechanics, elements in a scene or in the dialogs between characters. The other section (called S2) has four different questions meant to ask about situations the game does not deal with, but that are still related to the reading. This was done in order to observe if there were any differences on the comprehension of different aspects of the reading and if that has some relation to the game being used.

Table 5. Questions on the Reading Comprehension Performance Questionnaire

Section	**Question**	**Type**
S1 (Questions the game deals somehow)	Q1. What does Ole place in the children's eye to put them to sleep?	Literal
	Q2. Was Víctor a well-behaved kid?	Inferential
	Q3. When did the flowerpots change, before or after Víctor went to sleep?	Inferential
	Q4. What do you think about the letters Ole finds?	Opinion
S2 (Questions the game does not deal with)	Q5. What is the color of Ole's dress?	Literal
	Q6. Víctor made a mistake in his math homework?	Inferential
	Q7. When did they start spitting on the spittoon?	Inferential
	Q8. What do you think about the painting Ole gives life to?	Opinion

There are three types of questions: literal, inferential and opinion. The types of the four questions on each section are as follows: One question is a *literal comprehension* question, i.e. the answer can be found explicitly stated in the text; Two questions are *inferential comprehension* questions, i.e. the reader has to imply the answer from the text and one *opinion* question, i.e. the reader has to judge some aspect of the text read.

The *literal comprehension* and *inferential comprehension* questions were analyzed using a quantitative approach. With the help of a reading comprehension expert, the answers to the literal and inferential questions were scored with a set of criteria defined for each question. Then, each answer was scored from 0 (worst score) to 5 (best score) according to the defined criteria. Since the third type of questions (questions 4 and 8) asked for an opinion, it cannot be "good" or "bad", thus it cannot be scored. Hence a categorization was conducted on the answers the students gave.

For this study, in order to obtain the self-report on interest and motivation during the experience (research question aspect RQ1b), the Intrinsic Motivation Inventory (IMI) was used (Ryan, 2006). This inventory uses a set of sub-scales each one with a set of questions which use a Likert scale for the measurement. The chosen sub-scales with the respective Cronbach alpha values were: Interest/Enjoyment (*alpha* = 0.81), Perceived Choice (*alpha* = 0.72), Value/Usefulness (*alpha* = 0.65), Pressure/Tension (*alpha* = 0.76), and the Text Material Questionnaire (*alpha* = 0.79). The scoring and motivation data were analyzed in order to answer the first research question (RQ1): *Do students benefit in terms of reading comprehension while using an ARGBL game?* For this, a T-test was conducted on the data to answer the question: *Is there any relationship between the use of the ARGBL game and the performance in reading comprehension?*

Besides that, in order to gain more insight into the students' data, a comparative analysis was conducted considering three additional sub-questions for RQ1 as presented in Table 6 with the corresponding analysis that was conducted on each one.

Table 6. Sub-Questions and techniques used in the quantitative analysis

Sub-Question	**Analysis Technique**
SQ1. Is there any significant difference in the scores on the first/second section of the comprehension questionnaire between the children in both groups?	Mann-Whitney U Test
SQ2. Is there any significant difference in the scores for the first section and the second section, controlling by groups?	Wilcoxon Test for paired data
SQ3. Is there any relationship between the use of the treatment and the self-reported motivation of the children?	Mann-Whitney U Test

3.3.2 QUALITATIVE DATA COLLECTION AND ANALYSIS

More than 400 minutes of video of the interaction of children with the game and the book were recorded. In order to answer RQ2, these videos were categorized in the different phases of the process. For the analysis, the videos were transcribed in transcription files where each transcription file corresponds to a particular child.

In order to gain insights into the actions and interactions occurring during the sessions, a codification of the transcription files under the principles of Grounded Theory was conducted (Cohen, Manion, & Morrison, 2007). The codification was bottom-up, i.e. the interactions of the children were coded at a very granular level. The coding was inductive and non *a priori* categories were used. Then, the codes were reorganized looking for generalizations and joining similar codes. The codification was done by the main author; however, a weekly revision of the themes and codes was done with the remaining authors in order to check on the validity of the codification and structuring of the codes in themes. The themes were reviewed by the authors and the codes were checked against their corresponding exampled (citations) in the actual transcriptions and videos; disagreements were conciliated with arguments. This process resulted in a set of codes grouped in themes according to the interests of the

research. Since the research question RQ2 points to the "enrichment" of the reading activity, final themes represent actions performed during the session that enrich the activity and develop soft skills.

3.4 RESULTS OF THE DESIGN EXPERIMENT

This section described the results found after the quantitative and qualitative analysis. The quantitative analysis was able to gain some interesting insights. From the performance perspective, no significant differences were found in the scores of the questionnaire among the students in both groups (experimental and control). This is true for the consideration of the scores as a whole as well as divided by the two sections mentioned previously. However in the motivation perspective, the study did find differences in the self-reporting questionnaire, favoring the use of the ARGBL intervention. The qualitative analysis allowed observing beyond the outcomes of the experience. This analysis showed deeper insights into the behavior of the children.

3.4.1 ASPECT RQ1A - PERFORMANCE BENEFITS IN READING COMPREHENSION

This section explains the results for the questions regarding the reading comprehension performance (RQ1a, First two sub-questions in Table 6). For the research question RQ1: *Do students benefit in terms of reading comprehension while using an ARGBL game?* Under the performance perspective, a score was calculated by summing the individual scores on each question. It is important to highlight two questions were opinion questions (Q4 and Q8) and they were not included in this analysis; this resulted in the analysis including 6 questions only. Since there were 6 answers this score ranges from 0 (all the answers in the worst score possible) to 30 (all of the answers in the best score possible).

The media comparison using a T-test (t = -1.02, *p-value* = 0.72) did not show any differences between the control group (M = 17.42, SD = 5.71) and the experimental group (M = 16.84, SD = 3.43) with a very small effect (η^2 = 0.02). The raw data did not have a normal distribution according to the Shapiro-Wilk test (*p-value* = 0.01). So, a data transformation was performed using the Log_{10} of the score. The distribution of the transformed data was normal according to the Shapiro-Wilk test (*p-value* = 0.64). Homoscedasticity was assumed according to the Levene test for equality of variances (F = 0.125, *p-value* = 0.72). This was also true for each of the school grades. Among the same graders, there was no difference at all between the control group and the experimental group (*p-value* > 0.05) as they were all with no more than moderate effects (η^2 <=0.14). However, as expected, there was a tendency for the score to be higher, the higher the grades were. The data for each of the grades is shown in Table 7.

Table 7. Results for the scoring comparison for each grade

Grade	**Control**	**Experimental**	**Effect size (η2)**
Third	M = 16.62; SD = 7.22	M = 16.50; SD =2.07	Very Small (0.034)
Fourth	M = 17.00; SD = 1.63	M = 15.60; SD = 4.66	Very Small (0.043)
Fifth	M = 18.25; SD = 4.97	M = 17.71; SD = 3.14	Very Small (0.004)
Sixth	M = 20.33; SD = 5.46	M = 17.40; SD = 4.77	Moderate (0.088)

Regarding the sub-question SQ1: *Is there any significant difference in the scores on the first/second section of the comprehension questionnaire between the children in both groups?* The score variable was calculated for the first section of questions (calling it S1: Questions the game deals somehow) and the second section of questions (calling it S2: Questions the game does not deal with). Unlike the general score, S1 and S2 range from 0 to 15, since they consider only 3 questions each. To answer the sub-

research question a Between-Subjects comparison was applied. The distribution for S2 was normally distributed according to the Shapiro-Wilk test (*p-value* = 0.12). However, the distribution of S1 was not (*p-value* = 0.008), even after several attempts to transform the data. Hence, it was decided to apply a non-parametrical test: the Mann-Whitney U test. Results from the U-test failed to find significant differences between the groups for the S1 variable (*p-value* = 0.56) and the S2 variable as well (*p-value* = 0.501) with both with small effect sizes ($r < 0.1$). Again, the same was true for each of the grades as analysis for each of the grades failed to find significant differences. Table 8 shows the results of the analysis for each of the grades for each of the sections.

Table 8. Results for the Sections 1 and 2 for each of the grades

Grade		Control	Experimental	Effect size (r)
Third	**S1**	M = 9.57; SD = 2.29	M = 9.50; SD = 1.77	Very Small (0.06)
	S2	M = 7.14; SD = 2.73	M = 7.00; SD = 2.44	Very Small (0.06)
Fourth	**S1**	M = 10.00; SD = 1.41	M = 8.00; SD = 2.82	Medium (0.34)
	S2	M = 7.00; SD = 1.41	M = 7.60; SD = 1.94	Small (0.13)
Fifth	**S1**	M = 9.75; SD = 3.28	M = 11.57; SD = 1.81	Medium (0.36)
	S2	M = 8.50; SD = 3.58	M = 6.14; SD = 3.80	Small (0.27)
Sixth	**S1**	M = 11.66; SD = 2.50	M = 9.20; SD = 3.70	Medium (0.45)
	S2	M = 8.66; SD = 4.67	M = 8.20; SD = 1.30	Small (0.17)

Regarding the sub-question SQ2: *Is there any significant difference in the scores for the first section and the second section, controlling by groups?* To answer this, the same scores calculated above were used (S1 and S2). A Within-Subjects comparison was performed. The Wilcoxon test for paired data was used. Significant differences with a medium effect size were found between the answers in the section S1 and the section S2 for both the control group (*p-value* = 0.008; $r = 0.37$) and the experimental group (*p-value* = 0.005; $r = 0.39$).

As has been mentioned, the opinion questions (Questions Q4 and Q8 in Table 5) were not scored as being correct or incorrect. To perform the analysis the opinion questions were tagged by a blind evaluator. The codes were used to describe the type of answer the children gave (Table 9). The codes used in the tagging were categorized under the groups *Positive* and *Negative* codes. An answer was tagged freely and the tagging could include one or more codes.

Table 9. Codes Used in the Tagging of Opinion Questions

Group	Code	Description (The answer…)
Negative	**Simple**	Uses one or two words
	Copied	Is an exact copy from his or her partner
	Evasive	Does not relate to the question
	Incoherent	Does not make sense
	Not according to Text	Does not relate to the book

Group	Code	Description (The answer…)
	Biased	Is answered according to game graphics or Illustrations
	Does not Know	Is "I don't know"
	Empty	Is Empty
Positive	**Informed**	Uses information from the book
	Strong	Suggest that the child is sure about it
	Long	Is long
	Descriptive	Describes correctly aspects of the story
	Uses Context	Relates other aspects in the story

After the tagging was done, for each question, the frequencies of each code were analyzed, resulting in the distributions shown in Figure 23. The analysis was conducted with a chi-squared test. In the diagram, codes marked with an * show significant differences ($p < 0.05$).Significant differences were found in the code "Incoherent" where the control group got 23% more incoherent answers than the experimental group in Q4 and "Does not know" where 15% more answers were tagged this way for the control group in Q8.

According to these results, the answers were similar between both groups but some interesting highlights can be identified:

- Children in the control group tended to give more simple answers than the experimental group in both questions (Q4 and Q8).
- Children in the experimental group copied more in the question Q8 (the question the game did not deal with) than in the question Q4 (the game dealt with it).
- The control group has significantly more incoherent answers in the question Q4.
- The control group has more answers with "I don't know" in the question Q8.
- More answers in the experimental group were tagged as informed answers for both questions (Q4 and Q8).

Judging by the positive tagging in the *opinion* questions, students using the game tend to outperform children not using it. Also, it reveals again the importance of including elements of the reading into the game experience in order for children to identify elements in the accompanying book when using the ARGBL strategy. Results on the negative tagging suggest that children in the control group do not perform well in the question the game deals with, suggesting that the game experience benefits the students in the experimental group by giving them extra help to aid in their answers. All of this shows that the ARGBL game may affect the reading comprehension by aiding students to answer in an informed and complete (positive) way rather than a simple, evasive or incoherent (negative) way.

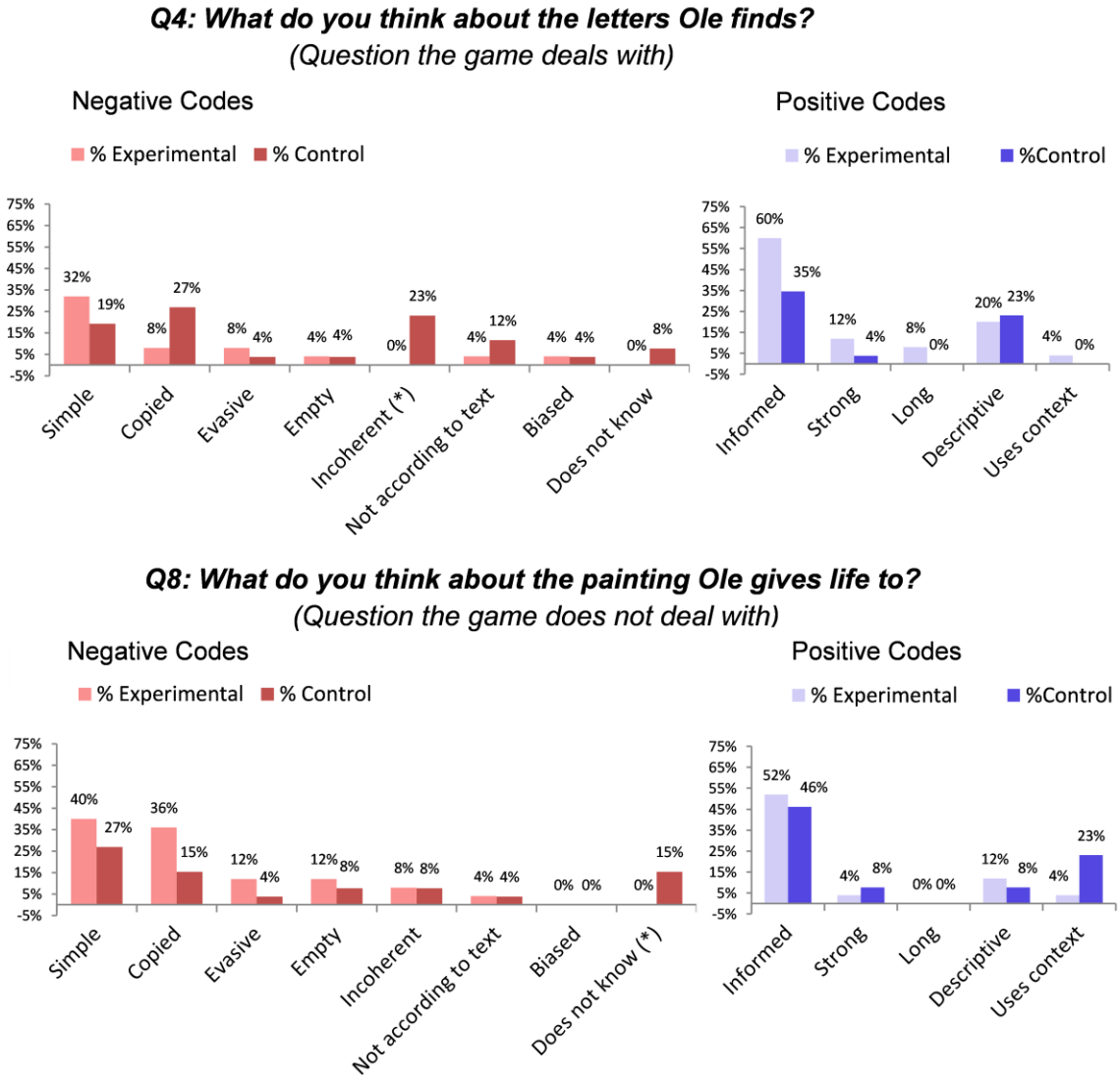


Figure 23. Results of the analysis on the tagged answers to the Opinion Questions. An * shows significant differences according to the chi-squared test.

3.4.2 ASPECT RQ1B – MOTIVATION BENEFITS

Regarding SQ3 from the aspect RQ1b *"Is there any relationship between the use of the treatment and the self-reported motivation of the children?"* As suggested by the IMI (Ryan, 2006) the scores on each question were averaged for each subscale. The means of the self-reported score of the IMI were compared as shown in Table 10.

Table 10. Descriptive statistics and results of the comparative analysis on the motivation questionnaire scores. The symbol * indicates significant differences found

IMI Subscale	Experimental (ARGBL)		Control		p-value
	M	SD	M	SD	
Interest/Enjoyment	4.69	0.39	4.38	0.61	0.018*
Perceived Choice	4.37	0.72	4.27	0.85	0.742
Value/Usefulness	4.60	0.64	4.61	0.45	0.450
Pressure/Tension	1.74	0.80	1.69	0.79	0.804
Text Material Evaluation	4.24	0.92	4.19	0.70	0.212

As it can be seen from here, the sub-scale where significant differences were found (favoring the use of the ARGBL treatment) was in the Interest/Enjoyment Subscale. Perhaps, this was to be expected since the game added a factor of engagement and motivation to the reading experience, and children seemed to enjoy the novel experience. The other sub-scales of the IMI show that children in both groups feel motivated and value their respective experience. This suggest that while both groups value the learning objectives of the game and the reading, children playing with the game feel it is a more pleasurable and enjoyable activity than the sole act of reading.

3.4.3 RQ2 – HOW THE READING COMPREHENSION ACTIVITY IS ENRICHED

How the reading comprehension activity itself is enriched? i.e. how enriched is the activity in terms of collaboration, problem-solving skills, argumentation skills etc. After the revision, coding and content analysis of the transcribed videos a set of observations and results were compiled; they are summarized in this section. Here the highlights of the experience are presented, telling the story of the children in the experimental group from the moment they start the game to the moment they finish it. This is presented, initially, in the form of a narrative of the events observed in the interaction with the game and showing some general aspects and particular observations. Also, a node graph shows the relationships of the themes and codes used while tagging the transcriptions. This was done as a way to perform a more holistic view of the observations made.

This narrative tells the story of the children interaction with the game in a somewhat chronological way. The intention is to show interesting observations that generalize the behavior and the most important events occurred during the experience. However, there are particular observations that are interesting and although they were scarce or *sui generis* they are very important as they can impact significantly a child's game and learning experience.

The narrative is based on the free coding conducted showing the codes used in italics. The researcher is indicated with an 'I' (Investigator/Interviewer). Transcriptions here are translated from the originals in Spanish.

BEGINNING

In the beginning, children showed much *interest* and *curiosity*. Some children were told by their classmates about the game, so they seemed excited prior to the activity. For example just minutes before the game some children mention:

- I: *I saw you very excited to come, why?*
- Carlos: *(raising his hand) Well, first of all, because this seemed very interesting and our classmates [were] telling "Wow, so cool!" we were curious to know what was going on.*
- I: *What do you think Valeria? (Also raising her hand)*
- Valeria: *Some [classmates] entered [the classroom] yesterday. I asked a friend and she told me it was very cool, so I wanted to come.*
- I: *And you Sandra?*
- Sandra: *I was curious too, because a friend told us it was very cool, so yeah, curiosity.*
- I*: What about you little Jacob?*
- Jacob: *I wanted to learn what we were going to do (…)*

Of course this can be only a "novelty effect", or maybe they just feel happy to participate in a different activity. They don't see the activity as something "educational" they have just heard it was fun.

Children were invited to play and try to finish the game. Younger children (3th grade) were told that this was a "magic book". When children pointed the camera to the book's cover, as the game states, the book "comes alive" which most of the time was followed with a gasp, emotion and excitement.

…The girls are around the book with the tablet in their hands
Josephine *checks the tablet and she is instructed to start the game*
The girls are told that this is a "magic book" and they are instructed a little bit about AR
Josephine *scrutinizes the camera and the device*
Josephine *points the tablet towards the book*
Julianna *accommodates the book*
- Julianna: *Ohh!! I saw it!! (She saw something in AR, she seems excited) There, there it is!!*
- Josephine: *Yeah!!*
- Julianna: *Ohh so cool!!*

Next, children used *to read the dialogs* and *text on the game*. This text mostly is the characters of the game explaining the "mission" on each scene. In the first scene, they have to help the elf to get "Víctor" and "Matthew" to sleep. Most children do *read the instructions* of the elf and they do as he says. However, some children won't read the text even after the elf recommends so. This was the case for Sebastian, a child from third grade, who did not read the text at all, but skipped the dialogue in order to win the game with other means like "*smashing buttons until something come out*". This is an excerpt of the interaction with him. He already had the tablet and had started to play even without being instructed to:

We see ***Sebastian*** *trying to play disregarding the instructions. He seems absorbed.*
- ***I:*** *(…) what did the elf told you?*
- Sebastian: *… (Does not answer)*
- I: *Don't you remember?*
Sebastian *denies with the head, and continues to play very concentrated.*
- I: *Well, maybe that is because you started smashing buttons, look… (Tries to explain, but…)*
- Sebastian: *Done! They are asleep… (Indeed, they are, he managed to do it after trial and error).*

Sebastian here shows he is a "Killer" type of player, someone who want to destroy and complete, rather than learn and explore (Bartle, 1996). From the interview, it was seen that Sebastian is a child very used to highly action games; he said he played *GTA V* a lot. Maybe he rarely read anything in the games and here we saw how he did not care for the elf's instructions, he wanted to smash buttons right away. Sebastian's case was an exception, but it is very important since the reading comprehension comes from the reading of the book and the game, and the children not reading may signify a problem since most of the time they will find themselves lost on the goals of the game. Also we see that a game goal attainable by trial and error is not desirable since it does not always encourage the player to read the text. This is also an instance of "attention tunneling" which is important as it may be potentially hazardous (Radu, 2014).

The elf in the game does explicitly recommend that they should read in order to complete each scene. In this point there are some children who *resource to read* and *explore the text* while others start *smashing buttons*, *exploring the game world* and *try by trial and error.*

Judging by the frequencies of the coding and the analysis by genre, girls tend to resource to the book more than boys. Boys tend to explore the game first.

For example in the case of Helena and María:

> ***María*** *and* ***Helena*** *are playing the game.* ***Helena*** *has already played the first scene.*
> ***María*** *tries some buttons in the first scene (the cover of the book portraits an intro scene).*
> ***- Helena:*** *Change the page.*
> ***María*** *reads aloud the text the elf Ole mentions in the game's dialogue.*
> ***- Helena:*** *Read here (instructing María).*
> ***María*** *reads aloud the text in the book.*
> ***- Helena:*** *There you go; you have to read the book.*
> ***- María:*** *yeah, wait…*
> ***María*** *continues to read the book.*
> ***- Helena:*** *read it all.*

For the case of Esteban and Santiago:

> ***- Esteban:*** *(asking to I) Do we have to read the text?*
> ***- I:*** *What do you think?*
> ***Esteban*** *and* ***Santiago*** *smile while looking at the book.*
> ***Esteban*** *reads the game's dialogue aloud.*
> ***Esteban*** *smashes buttons while* ***Santiago*** *holds the tablet.*
> *When* ***Esteban*** *and* ***Santiago*** *observe that the game recommends reading the book, they drop the device and start reading the book.*

After reading the first page, most children tended to divide the work via *collaboration.* This was sometimes explicitly, i.e. one child asked another to organize themselves with roles (holding the tablet, reading, etc.) while other couples just played along. In most couples there was a clear interest in solving the problem at hand, be it by reasoning over the text or playing the game directly. Most couples collaborating divided the work among the one who reads and the one who plays. And often they alternated those roles when they felt comfortable. This was natural as it is a group activity and AR has shown improvements in group collaborations (Radu, 2014). Nonetheless there was also the rare but interesting case, where this relationships became problematic, since the apparent "collaboration" was not more than one of the children *monopolizing* the learning material (mostly the game and the device). Here is a nice interaction between Samuel and Angela:

> ***- Angela:*** *(reading the text on the Matthew character) "He does not do his homework"*
> ***- Angela:*** *Ahh, I get it!*
> *(Talking to Samuel) You have to put this (an umbrella) over here (a child in the game)*
> ***Samuel*** *follows her instructions*
> *When that is done, Ole, the Elf, show and says it is not done correctly…*
> ***- I:*** *What does he say?*
> ***- Angela:*** *"The umbrellas are not correctly assigned"*
> ***- Angela:*** *(to Samuel) Told ya!*
> ***- Samuel:*** *ummmm.*
> ***- Samuel:*** *You told me to hit there!*
> *(He confronts her)*
> *(…)*
> *They keep chatting and argue about the game for a while…*
> *(…)*
> ***- Angela:*** *So this one is here, and this one here (she proposed, pointing to umbrellas and children).*
> ***- Samuel:*** *OK (Checking and analyzing her proposal).*
> *(…)*
> *After a while they continue this dynamic and manage to finish the scene.*

And here is an example between Pablo and Esteban. Pablo monopolizing the material:

> ***Pablo*** *and* ***Esteban*** *are playing but* ***Esteban*** *mostly observes.*
> ***- Pablo****: Bring it [the book] here* ***Esteban.*** *(In a rather demanding tone)*
> ***Esteban*** *accommodates the book.*
> ***Pablo*** *practically plays alone, without commenting what he is doing.*
> *Sometimes* ***Esteban*** *tries to play clicking the screen, but it is evident how* ***Pablo*** *monopolizes the tablet.* ***Esteban*** *has to make a big effort to look at what* ***Pablo*** *is doing in the game.*

At first some children seemed to be struggling with the new technology, while trying to overcome the game and reading to do so. This echoes with the notion of cognitive overload discussed by Dunleavy et al. (2008). Also the prototype had some issues in usability, and this is a potential detriment of the experience (Ferrer, Perdomo, Rashed-Ali, Fies, & Quarles, 2013), most children did accomplish the tasks and showed perseverance to obtain the goals in it and overcome eventual issues in the user experience. As Radu (2014) mentions, as he explores previous studies, there seems to be a pattern where children do recognize problems in usability but they also show willingness to use AR devices and experiences. As seen here, children did show some concerns at the beginning but when they got used to the system they got carried away with it easily.

Another interesting aspect is that children tend to "request" a one-to-one relationship of the game with the book. Children expect the game to be as similar as possible to the contents in the book. For example, in the first scene, in order to make it more interesting we added a second boy "Matthew" inexistent in the book – where there is only "Víctor" – and we saw Josephine and Julianna interacting as follows:

> ***Josephine*** *and* ***Julianna*** *are playing and reading.*
> ***Josephine*** *reads the behavior of each child (in the game).*
> ***- Josephine:*** *So, do I have to put the raining umbrella over the misbehaved boy?*
> *(The animation of the umbrella has some musical notes, they seem to rain. It is the one corresponding to the behaved boy)*
> ***- Julianna:*** *Yeah, and the behaved one deserves the non-raining umbrella*
> ***- I:*** *Read it there.*
> ***Julianna*** *reaches to the book and starts reading it, she looks curious, attentive and concentrated.*
> ***Josephine*** *finds the names of the boys.*
> ***- Julianna:*** *(to* ***Josephine****) which one is the misbehaved?*
> ***- Josephine:*** *Matthew (Note they concluded that, it is not explicit in the game)*
> ***- Julianna:*** *Look, there is Víctor (in the book)*
> ***. Josephine:*** *What about Matthew?*
> ***- Julianna:*** *No, but Víctor…*
> *(Matthew does not appear in the book, it is only an artifact in the game)*
> *Both start reading the book attentively*
> ***- Julianna:*** *I'm looking for the name of Matthew… It has to be somewhere.*

MIDDLE SCENES

In the second scene the answer is not that straightforward as it can't be attained by trial and error. The scene happens in the room of Victor, the elf asks for help to redecorate it. The kid has to make the plants grow and then they have to decorate the tree as the elf Ole does in the book.

While playing and collaborating in this scene, children showed *desire to act* and *desire to play.* Also, most children show a desire to solve the problem in the game. And it seems the interaction with each other is very important to this. It becomes evident when students *propose ideas, make hypothesis* about what they should do and the presupposed outcome of the game with certain actions. They also *analyze the text* and *explore the text* in order to gain more insights, clues and other elements to solve the problem. Most of these actions come after the children read the book.

They seem very eager to understand and comprehend the text in order to act within the game. The following is an example of an interaction:

Diego *and* ***Santiago*** *are playing the game in the second scene.*
- Santiago: *It says we have to help him organize the room*
Diego *tries to manipulate the plants with the elf's magic and they become trees.*
- Santiago: *That's it, look it says (in the book) that the plants transformed in big trees.*
(He makes a comparison between the game and the book)
It says it is until they [the trees] were as high as the roof
Diego *finishes transforming the plants and the scene where they have to decorate the tree appears.*
Diego *and* ***Santiago*** *start reading the book, they seem eager to read in order to inform themselves about the contents in the book.*
(…)
- Santiago: *(talking to Diego while reading the book literally) "There was not any branch without at least a flower".*
Santiago *then gives instructions to* ***Diego*** *on how to place the flowers in the tree. They try it together.*
Santiago *reads the book literally and aloud. Then* ***Santiago*** *comments to* ***Diego*** *about the fruits also mentioned in the book.* ***Santiago*** *reads some parts textually to* ***Diego*** *as he wants to make his partner observe certain details, in order to come up with a solution. This is very frequent.*
(…)
Diego *and* ***Santiago*** *communicate with each other, and they argue about what has to be put in the tree.* ***Diego*** *is the one in charge of the game.*
Diego *puts some decorations on the tree*
- Santiago: *I think it is done.*
- Diego *presses the "OK" button.*
The game shows "the tree is incorrectly decorated"
- Santiago: *"So, this goes here…" (Rethinking and tinkering on the game)*
Diego *mumbles something to himself, apparently reflecting on what to place on the tree.*
Then ***Diego*** *places some decorations*
The process of arguing and communications continues. They experiment with the game and try some ideas, always trying to follow the textbook contents. And finally they manage to finish the scene.

In the third scene, children seem eager to read. In this scene, there are two types of magically-animated letters: the well-written letters and the badly-written letters of Víctor. The elf asks for the help of the children in order to fix Victor's letters. At this point they have understood the dynamics of the game in which the book has to be understood and comprehended before getting to solve the problem. So the code *resource to the book* is more frequent the more scenes they advance. Also, at this scene, boys and girls tend to read even before the elf's dialogue asking for help, meaning that they have understood the importance of reading the book.

Children understand correctly the relationship between the textbook and the letters in the game, separating those well and bad written because of the illustration on the characters in the game. The following is an example of this:

- I: *What did you read Isabella?*
- Isabella: *That there were letters [in the book], upper and lower case letters.*
David *(at her side) is pressing buttons by the trial and error approach.*
- I*: Which are those letters? (to Isabella)*
- Isabella: *These… and these (pointing to the tablet) are the well-written letters…*
(…)
Isabella *reads a little bit more for a while.*
(…)
- Isabella: *Ok, so I think we have to do this… (…) Move the letters and organize them right? (She is not sure) make them pretty… (She is almost right, although the letters don't have to be moved, the elf has to make them exercise, with the gymnastic icon in the magic tools of the elf).*
- Isabella: *Like this 'B' letter, it would transform into something like this (pointing to the well-written letters). This one is prettier so I think I have to move them to here (Then she tries to drag & drop the letters. That is not the right mechanic)[Note how she is making a supposition based on what she has read]*
- I: *You think so?*

- Isabella: *yeah…*

Continuing with this case; note another interesting observation. Some children read the paragraphs by parts, and they try to hypothesize based on what they have just read:

- I: *Did you read the entire paragraph Isabella?*
- Isabella: *I read until here (She points to the book; she read only half a page)*
- I: *Ok, so you should read more then. I think you have to read all the text.*
Isabella *reads the text.*
- Isabella: *Do we have to alleviate the letters?*
- I: *Right, How?*
Isabella *reads the book again.*
David *keeps on playing, with no success.*
- Isabella: *(reading the book aloud) "…stroke without lifting the pencil" (Note how she tries to reflect and come up with answers by just reading parts of the text. Sometimes this works, but others it can be misleading)*
(…)
Isabella *reads the book attentively. After some more reading she comes up with an idea…*
- Isabella: *(reading literally) "… so, we shall give them a purge", a purge?*
- I: *Yeah? Try it.*
Isabella *turns towards* ***David*** *who has the game in his hands.*
- Isabella: *(to David) which one is the purge?*
- David: *This, here (he points to the purge icon in the game) But they [the letters] say "No, no. (In the game the letters respond very scared to the purge, as well as in the book. Note how David has already tested this)*
- Isabella: *(to I) it's not working.*
- I*: Then maybe that's not the right way, keep on trying…*
- Isabella: *Where was I?*
Isabella *reads the book again*
Isabella *reads and after that, she comes up with the idea of making the letters exercise*

FINAL SCENE

In the final scene of the game, children tended to go straightforward to reading even before the elf's dialogue. They seem to have understood how important was to read. Of course, at this scene, most children who were reluctant to read, were not as eager to read as their partner, but still, they did recognize it as an important part of the game. This scene deals about the part of the tale where Ole transforms the furniture of the room into vivid characters. The goal of the game is to transform the furniture with the right tools used in the textbook. Here is the case of Esteban and Pablo. Remember that Pablo in the first scene was monopolizing the game, however, in this scene; they have switched the control of the device and the book:

Esteban *is the one playing now.* ***Pablo*** *is not playing with the game.* ***Pablo*** *is kind of distracted with something in the surroundings (he is looking away, it is not clear to what).*
Esteban *tells something to* ***Pablo*** *and calls to his attention.* ***Pablo*** *then looks at the game and attends to what* ***Esteban*** *is saying*
There is a lot of noise in the ambient, but it seems they talk to each other for a while.
Both start collaborating in the game, they start playing.
Both play for a little while, to a point where ***Pablo*** *"claims" the tablet, he proposes he can do it better.* ***Esteban*** *agrees and allows him to use it.*
Pablo *takes the tablet and* ***Esteban*** *watches next to him*
- I: *What do you have to do* ***Pablo?***
Pablo*: We have to put these things (he refers to the elf's tools) to each object. (His answer is kind of vague, he does not seem so sure)*
- I: *Ok, but, how do you know that?*
- Esteban: *By reading this… [The book]*
- I: *Did you read it?*
- Esteban: *We understood we had to read it before anything.*
- I: *Ok*
After a while they manage to finish the scene.

When the game is over some children decided to start the game from the beginning, some replay previous scenes, others continue reading the book (but following chapters do not portrait a game) and others abandon the activity and continue with their regular activities.

AFTERMATH OPINIONS

After the experience, the kids were asked some questions regarding their impressions and opinions about the game and the whole experience.

When it was asked to the kids about what they thought about the game and the experience, the most common answer was that it was *Fun.* These are some examples:

> ***- I: Diana****, tell me, what do you think about the game?*
> ***- Diana:*** *It is like… well… it is like if you were living it, it is way more… I mean, One plays it and it is like something we had not seen, it is fun and it can teach you something, these are tales that you say "Wow, so cool, this is something I will always remember!"*
> *--*
> ***Santiago*** *is completing the motivation questionnaire.*
> ***- I: Santiago*** *what did you put in "Were you bored"? [A question in the questionnaire]*
> ***- Santiago:*** *I said "not at all", because I think it was so fun.*
> ***- I:*** *Why?*
> ***- Santiago****: Because the game showed you a hologram in the cellphone (he refers to the 3D augmented models in the tablet) so you could go playing instead of only reading…*

But children not only said they had fun during the experience, they also said it was *Educational, Interesting, Interactive* and *Immersive.* Some also said that they would prefer an interactive augmented game like this rather than a normal traditional reading activity:

> ***- I:*** *If you had to read the book or the augmented book-game, what would you choose?*
> ***- Juan Diego:*** *The augmented book.*
> ***- I:*** *Why?*
> ***- Juan Diego:*** *It is way more fun, you get to understand better.*
> ***- Danna:*** *Because at the end of the game you stay like "What happens after?" You leave curious.*
> ***- Juan Diego:*** *Yeah… in the book you read and you are like "What happens?" And then you play it and you get to understand what's happening*

This happened also with kids in the control group who played the game after only reading:

> ***- I:*** *What was better, the game or the reading?*
> ***- Valeria and Sandra:*** *The game! (Immediately and at the unison)*
> ***- I:*** *Why?*
> ***- Valeria:*** *Because it was more interactive.*
> ***- Sandra:*** *More interesting.*
> ***Valeria*** *nods*
> ***- I:*** *What do you think was more effective at making you remember the story?*
> ***- Valeria and Sandra:*** *The game.*
> ***- I:*** *But the reading has the same aspects of the reading within the game.*
> ***- Valeria:*** *Yeah, but the game makes you comprehend the reading, that way you remember more.*
> ***- I:*** *What do you think of the AR?*
> ***- Valeria and Sandra:*** *Cool!*

There are some that criticize the game. One of the main concerns are that the game can turn confuse and the "disappearance" of the game. This is related to the cognitive overload and the AR issues mentioned before.

> ***- I****: What do you think about AR?*
> ***- Jacob****: It's very cool"*
> ***- I****: Yeah? Why?*
> ***- Jacob****: I think it's interesting how the camera scans the book and shows 3D models.*
> ***- I****: Do you think it is educational?*
> ***- Jacob****: ummmm (he doubts) Learning? … (He thinks for a while) Yeah, I think so (But he does not look so sure)*

Learning, about the models and stuff (he is interested in the technological aspect of the experience). Because, otherwise, it is just a tale.
***- I**: And the tale. Is it nice?*
***- Jacob**: Yes.*
***- I**: What didn't you like?*
***- Jacob**: That often you get confused with stuff*
***- I**: Why? For example.*
***- Jacob**: Like the star, in the book it says it something shines, but in the game the only think shinning is the star (Actually the star does not shine, but the fruit does not either, so indeed, this is confusing).*

In the big picture, children opine that this experience was very useful and mostly, when they express themselves about it, they do not see it as a "homework" or "educational activity" but simply as a game. This concludes the narrative.

OVERVIEW OF THE THEMES AND CODES

Next, it is shown how the codes used related to each other. This is important as it helps to have classifications of the observations and it helps to propose future hypothesis in similar scenarios. During the qualitative data analysis, one of the main concerns was to answer "What actions do the children perform while playing the game in the experience?" For this, the codes were grouped depicting the actions of the children. The codes were grouped inside themes as depicted in Figure 24.

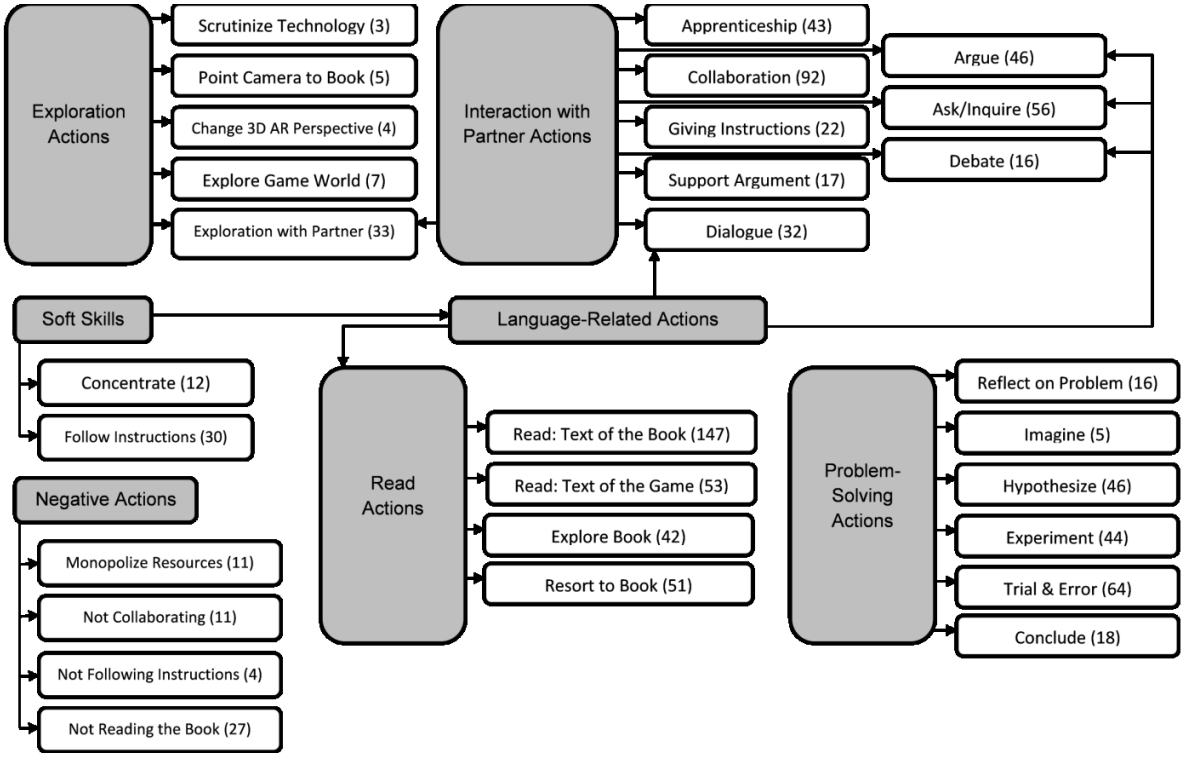


Figure 24. Codes depicting the actions of the children (shown in white). The clusters grouping the codes represent the themes identified (shown in gray). Numbers in parenthesis show the number of times the given code was observed (i.e. the grounding of the code)

One of the main themes regards children being involved in joint exploration (*exploration with partner)* in order to gain a first knowledge on the system as well as the game and the in-game world.

Children tended to interact with their partner as a common and natural outcome of the activity being in couples. These relationships include the children *collaborating, giving instructions* and performing some sort of *apprenticeship* as one of them guided the other one. Look how these interactions are

opportunities to develop language-related skills as the game and the activity focus becomes an excuse for *debating, arguing* and *supporting arguments.*

One of the most salient observations is how the *reading the book* code is the most frequent code. Most of the children did read the book and it was easily observable in the coded videos. Problem-Solving actions as well are a natural outcome of the activity. Children often engaged in the problem-solving processes such as *analyzing or reflecting on the problem, making hypotheses*, *proposing ideas* to their partners, conducting *experimentation* (proving their ideas inside the game), *corroborating ideas* and so on.

In many instances there were "Negative actions". These actions conduct to an underperforming of the activity such as kids *not reading the book* or *not following instructions (or ignoring them)* as discussed in the narrative.

The shown figure of codes and clusters is meant to give a holistic view of the observations conducted and feed future hypotheses as well as main conclusions in this study.

FINAL OBSERVATIONS AND LIMITATIONS OF THE ANALYSIS

As seen from our observations, the activity with the ARGBL game is far from a traditional reading activity in which (as expected and observed from the control group) children limit to read sequentially and ask few or none questions to teachers or peers. While in this activity we observe that aside from reading, children read, explore, experiment and seem very motivated and enjoying the experience. The following explains how the analysis of the observations was made to conclude this study. Once the themes had been identified and the hierarchy (Figure 24) was organized the themes were explored and the codes through examples of each, in search for conclusions that could be drawn for research question RQ2.

With the "Exploration Actions" theme, it was found that during the reading activity the students did not limit themselves to the actual reading text. Instead, they explored the various elements of the activity within the game (characters, game elements, etc.) and outside the game (the book, the device, etc.). This was done both individually and collaboratively. When it was collaborative, it often formed part of an ongoing debate where students argued with each other about the game and the problem to solve.

Related to this, the theme "Interaction with Partner Actions" shows a highly collaborative environment in which students strived to solve the problem the game presented. The process of resolving the problem included several social skills (identified by the appropriate codes *Arguing, Inquiring, and Debating*). An oft-seen code was *Apprenticeship* as students often engaged in a relationship of teacher-student, where one (the teacher) would guide the other.

The most frequent code was *Read: Text of the Book* in the theme "Read Actions". As expected, reading was one of the most-oft observed actions. Children would read the text sequentially, but they would not be limited to doing that. Children engaged in reading the text in the game and relating it to the text in the book to find answers, explore options and search for clues.

Other themes include the actions involving the practice of Problem-Solving and soft skills. The activity with the ARGBL game allowed these skills to be developed as part of the socially-bound activity of discussing with the partner and collaborating to solve the problem the game presented. Among these skills, students engaged in actions reflected by the codes: *Reflect on a Problem, Imagine, Hypothesize, Experiment, Follow Instructions,* among others. This echoes the notion that games, due to their nature, can be used as an excuse to develop these skills so very important for the future development of students in this century (Qian & Clark, 2016).The identification of these actions and the hierarchy in themes is proof of how the ARGBL enriched the reading activity in this particular scenario.

It is noteworthy that some "Negative Actions" were observed during the activity. They are important to bear in mind when applying a game with Augmented Reality and for future studies. These actions

included: *Monopolize the resources, Not collaborating, Not following instructions* and most importantly, *Not reading the book.* These actions are a threat to game's ability to enrich the activity and pose serious obstacles if designers and/or teachers do not consider them when designing or deploying ARGBL games.

Last but not least, the gaming-and-reading activity takes more time than the sole reading activity, especially for those children who come back to play it again (and again).

This study has several limitations. Mainly it should be acknowledged that these observations were held in a set of students from a mid-to-high socio-economic status where in many occasions parents encouraged children to read and, most of the time, these were genuine "Digital Natives", as they have lived and do live with technology surrounding them all the time. Thus, generalization of these results should also recognize other particular contexts such as other socio-economic environments.

The game used was a design prototype so usability and user experience issues were expected. From our observations in this sense, we can say that AR tracking techniques as we have them today are quite cumbersome, thus improvements in pattern recognition and tracking techniques are needed to include AR technology in the classroom in a more transparent way.

3.5 POSTMORTEM: IDENTIFICATION OF NEEDS FOR THE DESIGN OF ARGBL EXPERIENCES

After the execution of the exploratory scenario, there was in the project an empirical scenario that allowed the identification of a set of needs to improve the design of ARGBL experiences. This identification is shown here as a list of lessons learned that were used later as the considerations fro proposing the method of Co-Design shown and validated in the next chapters. Some considerations refer to the Teachers, because, while they were not the main focus of this study, they were certainly a part of the design and execution process, and thus, the interaction with them allowed observing interesting aspects that are taken as lessons learned.

The lessons learned and considered are:

- **Need for training:** Teachers are not aware of the capabilities and aspects of AR and/or GBL. Thus, before starting to work with teachers, a period of training is needed. This was observed when the work with Teachers started. Teachers were not aware of AR and/or GBL a training was needed.
- **Collaboration:** Although some teachers participated during the creation of this experience, the results were not as satisfactory as needed, particularly in the inclusion of educational content. It is important for the optimal conclusion of the ARGBL design that teachers participate not only as informers but as creative actors during the process.
- **Iterative design:** As shown in the exploratory scenario, one of the most important aspects was that there were subsequent iterations that helped on the design of the experience. This should be understood as an important aspect of the design, because it helps to improve the design, especially when including teachers not expert in AR or Games for learning.
- **Craftsmanship design over authoring:** The exploratory scenario revealed that there are still technical obstacles for the development of complex experiences involving games and AR. For that, it would be difficult to create an authoring tool, and it would be even more difficult for teachers to use it. The problem of creating such a complex artifact as an ARGBL game for learning is what some authors call a "wicked problem" (Buchanan, 1992) i.e. a problem where the solution is not trivial and require more "humane" approaches. This process used a "craftsmanship" approach, meaning that the ARGBL game was not created with an automated one-shot process, but as a carefully designed experience, much like the design of commercial videogames. This exploratory scenario led to the consideration that the craftsmanship

approach leads to create more complex and professional results, comparing to authoring approaches.

- **Usability and User Experience:** ARGBL is still hard to design and execute and this aspects worsens when user are not aware of the AR technology. Thus, design of the experience is important, and other aspects of usability can be controlled by professionals, but perhaps not by non experienced teachers or other creators. This suggests that there is a need for professional participants in the design and development process.
- **Complexity enriching the learning activity:** One of the most important conclusions of the exploratory scenario is that a complex game that relates to the educational content (in the exploratory scenario, the reading) lead to the enrichment of the learning process, improving soft skills, while motivating on the learning activity. This suggests that the creation of the game should consider that the game is not meant to be only a content-delivering artifact, but it can be used to exercise other important skills, such as social skills, problem-solving and so on. Thus, the design of the ARGBL game becomes a big endeavor which is benefitted by the participation of creative actors with different backgrounds.
- **Development by professionals:** Following the previous lessons, the work conducted in the development of the exploratory scenario lead to think that professionals on AR and Game design and development should participate in the process. This is because the current tools available to lowly-funded teams are designed to be used by professionals (designers, artists, programmers).
- **Evaluation in naturalistic environment:** The evaluation in the naturalistic environment helped to realize aspects of the ARGBL game that are important for it to develop correctly in the learning process. Thus, the ARGBL design process needs to consider the adequate time to evaluate the product in real contexts to get feedback from students, teachers and the interaction between all the elements in the class.
- **Design Based Research:** Since the ARGBL approach is new, design endeavors that work to bring ARGBL to the class benefit from a researcher in the process. This allows conducting observations and generates theories and design guidelines from the process that feed future works. In this exploratory process, the observations were conducted under the DBR approach, thus, it is recommended to follow its recommendations.
- **Adequacy of learning objectives:** Not every learning objective can benefit from ARGBL. This was a lesson learned from the exploratory scenario. While the ARGBL game promoted the training of soft skills, it showed how children did not performed better than the control counterparts. This suggests that the learning objectives of the ARGBL experience are to be defined based on the characteristics of AR and GBL. Thus, a process of specifying and analyzing the learning objectives is needed in order to have the optimal performance of the ARGBL game.
- **Design game goals according to learning objectives:** This is related to the previous lesson. The ARGBL has the need to be designed according to the learning objectives (and the educational content). This relationship is top-down, meaning that the learning objective is to be defined first, and then the ARGBL goals and mechanics. This way, the ARGBL guarantees that it is aiming to the learning objectives. This supports the idea that the process needs to be a long process of design, instead or a one-shot rapid design process, perhaps limited by the constraint of an authoring tool.

As the following chapters show, the work of ARGBL continued with the design involving the teachers as creative actors. The needs identified from these lessons were considered in the next stages of this thesis. The needs were addressed on the methods and technologies designed to support the ARGBL design and consequent introduction to the classroom.

3.6 DISCUSSION

In this exploratory scenario, it was investigated the application of an ARGBL game to a reading activity in a classroom environment. The ARGBL game was designed with the help of teachers and was an Augmented Book (based on a real story book) in which each page presented a different scene and a challenge for the player. The game was tested during a design experiment conducted under the principles of DBR (Barab & Squire, 2004), thus, the testing was conducted in a naturalistic environment which considered student context.

Judging by the quantitative results in this scenario, students who participated in the activity by just reading the book performed as well as those who participated by reading and using the ARGBL game. This suggests that including the game in the reading activity did not affect the children's reading comprehension scores. It also suggests that children retain the same information and can answer reading comprehension questions (literal and inferential) regardless of the way they participated in the activity. In this sense, it may be considered that the use of the ARGBL game, as it comes accompanied by the book, is equivalent to the reading experience using the book only.

To determine if the game helped students to correctly answer only those questions that the game included, this study divided the reading comprehension test into two sections, namely S1: "questions that the game dealt with", and S2: "questions that the game did not deal with". The analysis of the results showed that there is no difference between the groups or the sections, which would suggest that, once again, children comprehended the reading regardless of using ARGBL or solely the book.

The reading comprehension test used in the analysis of the performance of the children included two "opinion" questions. Since the opinion could not be "right" or "wrong" they were not scored; rather, they were tagged to identify specific features of the answers. The results were mixed. For Question 4 (S1) the answers were generally tagged in a more positive way for the experimental group and vice versa for the control group, meaning that the ARGBL game may have helped the children to answer in positive ways such as giving more informed, and stronger and longer answers. However, this was reversed for Question 8 (S2) which resulted in slightly more positive codes for the control group. For example, more answers were tagged "simple" and "copied" (negative codes) for the experimental group and more were tagged as "Uses context" for the control group. It is difficult to assert a clear conclusion in this sense; however, this seems to suggest that the game helped children to give more robust answers.

Up to this point it may seem hard to say what the advantage of using the ARGBL game rather than just using the book is. The advantage seems to be twofold: motivation and enrichment of the experience. This study performed a motivation test on the students using the IMI questionnaire. Four sub-scales of the IMI were used: Interest/Enjoyment, Perceived Choice, Value/Usefulness, Pressure/Tension and Text Material evaluation. The results showed that students in the experimental group were more interested or enjoyed the activity more than the students in the control group did. This means, that while students get the same scores regardless of the form of the activity, they enjoy using the game more than just reading the book. This may be related to the fact that they are playing a game, and the fact that this was a collaborative exercise. Along these lines, we can suggest that the use of Games with Augmented Reality in the classroom favors the interest in and enjoyment of the reading experience for children. In support of this, the observations as the reading activity unfolded showed behaviors that may elicit interest from the students to continue reading, thus, engaging the student in the reading activity. So, the game is used as "bait" (Steinkuehler & Squire, 2014) to both garner interest in the learning content, and as a tool to promote reading.

Finally, the exploratory scenario shows how the reading activity is enriched. The study performed direct observations of the students using the ARGBL game and showed a set of actions (benefitting the learning process) being put into play. Those actions included the peer relationships of students, the relationships with their teachers or guides, and actions involving the development of language-related

skills, like debating and arguing. Children were also interested in reading to solve the challenge they were given and showed not only sequential reading, but also read in search of clues using the text as another means to an end. Consequently, the qualitative and direct observations of the interactions with "AR Ole Cierraojos" during class time in a naturalistic environment, suggest that the reading experience takes on a whole new meaning by allowing the child to experience the reading from a new perspective, all the while developing soft skills. Therefore, the reading comprehension activity is improved as the child engages with the reading because understanding the text serves a purpose within the game.

3.7 CONCLUSIONS OF THE CHAPTER

An exploratory scenario was conducted on the utilization of an ARGBL game (called "AR Ole Cierraojos"). This was done in a naturalistic environment aimed to reading comprehension under a Design-Based Research approach performing both: quantitative and qualitative analysis. Based on the results shown previously the following conclusions can be drawn. A set of research questions guided these chapters (named RQ1 and RQ2).

From a quantitative perspective for RQ1 (*Do students benefit in terms of reading comprehension while using an ARGBL game?)*, the analysis did not show any statistical differences in reading comprehension between the group that only read the book (control group) and the group that performed the reading with the ARGBL activity (experimental group). Hence, judging by this data, the children's performance is the same regardless of the strategy used.

An analysis was done over a motivation questionnaire including several variables affecting motivation during the learning activity. From this analysis it was observed that there was a difference between the groups in the Interest/Enjoyment variable.

In terms of RQ2 (*How the reading comprehension activity itself improves?),* the qualitative perspective was used in which it was observed that the game with AR enriches the learning activity itself. This enrichment comes from a series of actions the game encourages.

To sum up, the exploratory scenario's contributions include an analysis of children's performance and motivation when interacting with an ARGBL game compared to a set of students who did not use the game. This analysis was conducted in a way similar to (Furió et al., 2015) but, in this case, the game was based on reading comprehension problems presented in an AR book. The game used in the scenario went further in that it not only applied AR as static imagery related to the reading, but also included a tailor-made game with problems to be solved by comprehending the text. This was done to compare this exploratory scenario with previous studies that used AR books that showed interactive imagery but not games (Cheng & Tsai, 2014; Dünser, 2008; Ramli & Zaman, 2011) and to studies that used the AR book not for reading comprehension but for word recognition (Ramli & Zaman, 2009b). The hierarchy of codes identified during the observations of the children interacting with the game helps future studies because the game enriches the reading activity. The exploratory scenario was used get information about the needs in the design of ARGBL experiences. These needs have been compiled in this chapter as a consequence of the lessons learned during the execution of the exploratory scenario.

This exploratory scenario is part of the ongoing interest researchers studying the implications of using ARGBL in the classroom have. As we can see from this, and from previous studies such as (Antonaci, Klemke, & Specht, 2015; C.-H. Chen et al., 2015; Furió et al., 2015; Gomes et al., 2014; H. Tobar-Muñoz, Fabregat, et al., 2014; H. Tobar-Muñoz, Baldiris, et al., 2014), in general, using these technological and pedagogical approaches benefits the learning experience, be it in performance, learning, knowledge, satisfaction or motivation.

The work in this chapter is thus one step more to get teachers and students closer with the use of digital technology involving AR and Games for Learning. The review on this thesis shows that there is a

lack of guidelines and frameworks to guide the process of design of ARGBL experiences with teachers. Observing the needs concluded in this exploratory scenario and observing the desire to include teachers in the design process a design method aimed to involve teachers in the used of games and AR for learning was proposed. The method is explained in further chapters.

PART THREE: SUPPORTING THE ARGBL DESIGN

4 METHOD FOR THE CO-DESIGN OF ARGBL GAMES WITH TEACHERS

As has been shown in the previous chapter, ARGBL approaches can benefit the learning process. Nonetheless, as stated by the needs and lessons learned shown in the exploratory scenario, there is a need to collaborate and include teachers in the process of designing ARGBL experiences. In fact, other stakeholders interested in the ARGBL experience may benefit it. However, as the problem of creating an ARGBL is difficult and is indeed a design problem, it classifies as a "Wicked problem" (Buchanan, 1992) that is not solvable by an automated tool. Rather, the creative participation of stakeholders is preferable. Stakeholders in the creation of ARGBL experiences include Teachers, Students and AR/Game Designers. However, there is still a gap between AR/Game Designers and the practitioner Teachers when they try to create ARGBL experiences. For this, in this thesis it was decided that a methodological approach would be a solution to guide the creation and inclusion of ARGBL experiences in the classroom.

To propose the method, first, a field experience was carried on with Teachers in order to find out *How to support teachers to design and implement ARGBL experiences.* This was used as a sub-research question in this thesis. It was decided to propose a Co-Design method since previous studies have proposed that the inclusion of Teachers and their involvement in the use of technologies for the classroom is important and beneficial (Cober et al., 2015; Dolonen, 2009; Roschelle & Penuel, 2006). Researchers have studied the advantages and Co-Design, like (Carroll et al., 2000; Dolonen, 2009; Penuel et al., 2007; Roschelle & Penuel, 2006) who state that Co-Designing with Teachers makes them interested and gain ownership on the final product while alleviating the burden of actual development. Sanders and Stappers (Sanders & Stappers, 2008) argue that the landscape of design is changing and thus, it requires new methods and tools to help the users to get involved in the creation of newer artifacts and experiences. Some studies suggest Co-Designing AR and Games for Learning. For example

Marc Santos et al. propose to get teachers involved in the process of creating AR Learning experiences (Santos et al., 2013) and, as they propose AR as a multimedia experience — a learning experience involving different types of media — they suggest that more and more teachers will participate on the creation of AR learning resources (Santos, Chen, et al., 2014). Yuen (2011) states that AR experiences created by small, perhaps formed by less-funded teachers, benefits from the work of interdisciplinary collaborators. While Games for Learning have a tradition of being designed only by Designers, some experiences have used the Co-Design paradigm with Teachers like the Proactive Project (Frossard & Barajas, 2011; Frossard, Barajas, & Trifonova, 2012; Proactive, 2011; Torrente et al., 2011) or with Students like (Bates, Brown, Cranton, & Lewis, 2011). Other experiences in Co-Design have also proposed strategies and tools to support the Co-Design of learning experiences, such as CoDICE (Díaz, Aedo, & van der Vaart, 2015).

This chapter shows a brief depiction of the background on Co-Design for learning that supports our approach. Then, the method is introduced; it is named Co-CreARGBL, and it considers the needs identified in the exploratory scenario and literature findings which include principles, uses and models (for both, AR and GBL). The method is meant to be a tool for project leaders and designers that desire to work along teachers in natural environments when proposing new ARGBL experiences. Co-CreARGBL was proposed and validated during the case studies conducted in Popayán, Colombia with a set of teachers designing ARGBL experiences. The validation results are shown in part three of this thesis.

4.1 BASES OF THE METHOD

The method proposed here has roots in the literature. In this section, the prior related work is shown depicting how Co-Design has been proposed to be used in education along with teachers. Co-Design is considered to be an instance of Co-Creation, which is used generally as a wider term. While Co-Creation is a term involving any act of collective creativity, Co-Design is interested mainly in the design of new artifacts, in particular technologies (Sanders & Stappers, 2008). That new paradigm of design is highly interested in involving users and not only those that "lead" or show themselves as "creative", but anyone who has the passion to actually create out of their own inspiration.

Co-Design comes from the —now decades old— tradition of *Participatory Design (PD)* (Kensing & Blomberg, 1998; Muller & Kuhn, 1993; Sanders, 2002). It is a tradition that started in the 1970's in north Scandinavia but that now is permeating several fields of design around the world. It can be understood as a paradigm, but others have stated it to be a methodology. In any case, the method proposed here is inspired by these traditions in order to propose a process that benefits Researchers, Designers and Teachers and, in turn, the Students.

4.1.1 CO-DESIGN FOR LEARNING

Although PD started in the 1970's, Co-Creation and Co-Design gained momentum in the 1990's especially as the *Corporative Co-Creation with Customers* strategy applied in the marketing fields (Ramaswamy & Ozcan, 2014), it is more recently that Co-Design and Co-Creation have been proposed as paradigms with methods and tools to be used in the design of technology for learning. Penuel, Roschelle and Shechtman (Penuel et al., 2007; Roschelle & Penuel, 2006) define Co-Design for learning as a:

> *"highly-facilitated, team-based process in which teachers, researchers, and developers work together in defined roles to design an educational innovation, realize the design in one or more prototypes, and evaluate each prototype's significance for addressing a concrete educational need"*

Co-Design for learning has many aspects in common with other traditions of participatory design (Roschelle & Penuel, 2006) like:

- *Rapid Prototyping:* This involves the creation of new artifacts by means of constructing prototypes that depict their aspects. In Co-Design, the rapid prototyping is desired as an iterative approach may benefit the understanding of all the parties participating.
- *Design-Based Research (DBR):* This is the research method that has been described in previous chapters. It aims to design learning artifacts and observe them in natural environments. Researchers participating in a Co-Design endeavor are centered on analyzing and proposing theories regarding the insights into the built artifact.
- *Team-Based Design:* It refers to the methods of design where several people (forming a team) are in charge of designing an artifact or innovation. In Co-Design a team must participate in order to build the artifact also.
- *Learner Centered Design:* This design strategy aims to design learning experiences and artifacts by observing the needs and context of the learners. In Co-Design for Learning there is still a need to build the artifact aiming to solve the needs of the learner as the final user.

As Roschelle and Penuel (Roschelle & Penuel, 2006) mention, Co-Design for Learning is related to research methods like DBR, because both try to design innovations for the classroom, involving real teachers and students. Co-Design is also related to *User-Centered Design*; nonetheless, Co-Design tries to go beyond by considering that anyone can be creative and thus, a deeper involvement of the consumers and clients (e.g. teachers and students) is needed (Sanders, 2002). Figure 25 depicts this situation.

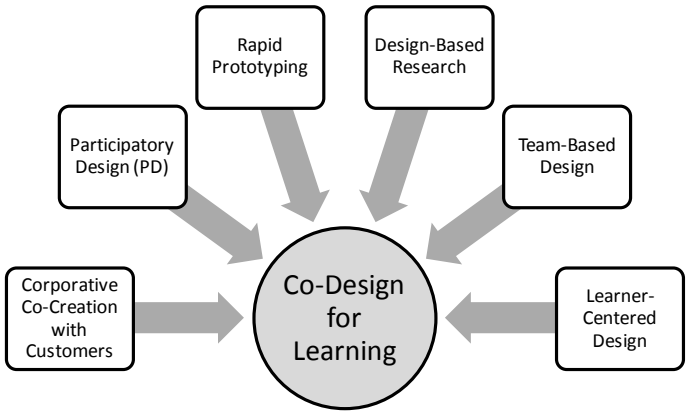


Figure 25 Co-Design for Learning is related to other traditions of Design of Innovations

In the last decades, some experiences have started to show applying Co-Design to the development of educational resources; in particular, digital educational resources. One of the earliest experiences is that of Carroll et al. (2000) where they describe an experience conducted with Teachers in order to design an educational software. This experience, pioneer in this aspect was conducted between 1994 and 1998 and it was reported just by the year 2000. From this experience reflections were done over the issue of "tensions" (see Dolonen, 2009; see Penuel et al., 2007) that arise when working with Teachers on a Co-Design endeavor. For example, some of the main tensions are the lack of time of Teachers, the lack of support from administrators and the lack of a sense of ownership on the product being designed. Other experiences include *Inquiry-Based design for learning* (Cortada-Pujol et al., 2015) and orchestration of CSCL[9] scenarios (L. P. Prieto et al., 2014). One of the more recent and well-detailed

[9] Computer-Supported Collaborative Learning

experiences is the one carried by Cober et al. (Cober et al., 2015). In this experience, authors described two experiences designing software in a Co-Design environment with Teachers. They also include the tensions that arose, the tools and solutions they proposed to Teachers and other main observations, grounding their theory on techniques like interviews and field observations. Co-CreARGBL is based on these findings since those experiences explore the main issues that a Designer or Researcher should have in mind in order to organize better their job.

4.1.2 CO-DESIGN OF GAMES FOR LEARNING

GBL has already attained a state where there are several experiences that show how games can improve the classroom experience and the whole learning process. Due to this, it is relatively easy to find in the literature, several approaches, views, frameworks, models and methods to design and research on games for learning as shown in a previous chapter. Unlike this, Co-Design of games for learning is very new to the design landscape, and thus it is difficult to find works related to the designing of games involving Teachers, Designers and Researchers alike. It is a shame, because as GBL grows, it could benefit from the use of Co-Design strategies just as any other pedagogical approach.

Anyways, while there are not, to the extent of our knowledge, methods and frameworks for the Co-Design of games for learning with Teachers, Designers and Researchers, some experiences have shown guidelines (Frossard, 2013; Mellini et al., 2011) and recommendations (Proactive, 2011) that guide the process of designing and creating Games for Learning. This is the case of the ProActive project (Proactive, 2011). This work described several experiences in Spain and Italy about how teachers can work along to create digital point & click[10] narrative experiences using the <e-adventure> authoring system ("eAdventure," 2014; Marchiori et al., 2012; Torrente et al., 2008). Note, however, that these experiences include the Co-Design of teachers without the inclusion of professional game developers. And this requires teachers to create their experiences using the authoring tool. Our proposal is different since it involves professional game developers to alleviate the burden of actual construction from Teachers while leveraging more professional results.

Also, some empirical efforts can be found like the work of All, Looy and Castellar (2012) who worked designing a game for traffic safety collaborating with students and teachers. Most of the empirical works will not define or abstract a method. For now, most efforts including some kind of Co-Design or PD limit themselves to the description of the experience in terms of design, development and issues found.

It is worth to mention here, that while the approach of Co-Designing Games for Learning is relatively new, and thus, the right constructs, methods and frameworks haven't been collected yet, the design of Games for Learning in a more general sense has already been studied and there are several (perhaps too many) works that propose models, methods and other constructs to guide the design of Games for Learning. One notable example of such methods is Rugelj's process called SADDIE (Rugelj, 2015) which proposes an instance of the traditional process of ADDIE for instructional design (Branch, 2010).

4.1.3 CO-DESIGN OF AR FOR LEARNING

AR for learning has likewise been developed in the latest years. Some researchers have proposed principles for the design of AR experiences in the classroom like Cuendet, Bonnard, Do-Lehn and Dillenbourg (2013) who proposed a set of principles to include AR in the classroom and the learning

[10] A "point & click" game is one where the player sees a (often) 2D screen with elements and then point and click to them as the Main action. An example of this is the popular 1990 PC Game *The Secret of the Monkey Island*

processes: Integration, Empowerment, Awareness, Flexibility and Minimalism. Also, researchers have been proposing Co-Design in the development of experiences that include AR (Cuendet et al., 2013; Santos, Chen, et al., 2014; Santos et al., 2013). Some new experiences have entered the Co-creation and Augmented Reality for Learning landscape like the work of Bacca et al. (Bacca, Baldiris, Fabregat, Kinshuk, & Graf, 2015) where they describe an application to support learning in VET processes considering inclusive features. However, few to none works have studied *How* to conduct those processes.

While Co-Design of AR is also an approach relatively new, the design of AR for learning has been deeply studied and it is easy to find frameworks, models, guidelines and recommendations that are useful when considering the inclusion of AR in an educational resources. Those constructs include the uses of AR that the work of Santos et al. (2014) found, the affordances of Cheng and Tsai (2012), the directions of AR in education by Yuen (2011) and the other benefits of AR already mentioned in the state of art in this study. We also considered the Jerabek, Prokysek and Rambousek's Parameters (2013) which include the configuration of technological components, the number of users, the nature of control information and the nature of the interaction between the user and the system These works were analyzed to propose the method. Also we analyzed experiences held with the design of AR for classroom.

As has been stated, the union of AR and GBL is very new, thus Co-Design endeavors have not yet been done. However, this thesis has conducted a review (chapter 2) where it was shown that most endeavors in ARGBL have not included the collaboration with teachers. Moreover, the thesis has also shown an exploratory study which highlighted the need for the participation of teachers. It is the intent of this thesis to leap forward by proposing the participation of teachers in the processes of creation of ARGBL experiences, and thus, we argue that the gap in methodologies aiming to this purpose should be closed.

To sum it all up, we consider that the following issues arise from the analysis of works related to the Co-Design of ARGBL experiences.

- There is a lack of tools that seal the gap in designing ARGBL experiences between teachers and designers.
- While there are plenty of recommendations and guidelines to create AR or GBL experiences, there is not, to the extent of our knowledge an approach mixing them both.
- Most of the found approaches involve some kind of guideline or principle, while there is a lack of methods and processes that guide the strategy to build ARGBL learning experiences with teachers.
- While Co-Design is being recommended as a valid and effective strategy to leverage learning experiences in the classroom, there is little done about methods involving teachers and designers working on an ARGBL experience.

4.2 CO-CREARGBL METHOD

In this section, Co-CreARGBL is introduced and described as a method for Co-Designing games with AR for learning in the classroom. This proposal is guided by three stages that include the activities that the people involved should conduct and the roles that those people enact. The section explains the roles proposed and then it describes the stages to follow. The method is meant to be iterative which is why after the stages are culminated, further re-design can happen.

4.2.1 INTENDED USES

Co-CreARGBL method is not intended for every design endeavor, mainly because this method was created with the collaboration of teachers and designers in mind. The following are the critical characteristics of the design endeavors that Co-CreARGBL is intended to apply to.

- **Heterogeneous Groups:** The method is intended to guide groups that involve professionals (in AR and Games) and non-expert participants (the teachers). This includes the roles as defined in the next section.
- **Image-Based Games:** While the general principles and structure of the method could apply to bigger scopes (Location-Based AR, for example) the method's recommendations are mainly for Image-Based approaches. This was chosen because the gaming activities that could occur with AR at a classroom are more aligned to the capabilities of Image-based AR than they are to Location-Based AR. Location-Based AR requires the setting to have a bigger scenario and a game in this setting is perhaps not a playful experience but a gamified experience. However, this includes various types of Image-Based AR, shown in the classification shown in previous chapters.
- **Expert and non-expert Teachers:** Teachers are not expected to have experience on AR or GBL. Naturally, Teachers with experience on the use of playful activities or AR in the classroom are desired because they are expected to promote better ideas for the project.
- **Subjects:** The method is intended to be used with any subject. The method allows the inclusion of various subjects in the game.
- **Simple AR:** The method is intended to guide heterogeneous processes that include less-funded teams and members. Often, teams that are not well-funded cannot afford high-end devices or AR techniques. The method thus gives recommendations considering this restriction. The term Simple AR is used as used by (Siltanen, 2012) *"A simple augmented reality system consists of a camera, a computational unit and a display. The camera captures an image, and then the system augments virtual objects on top of the image and displays the result." (p. 19)*.
- **Complex Games:** The method is intended to create complex games rather than simple flashcards games. This is because, the simple games, that often can be created with authoring tools do not utilize at an optimal level the advantages of using GBL and/or AR.
- **Test in Natural Environments:** The method is intended to produce artifacts that are to be tested in environments where the natural interaction between teachers and students. This is following the recommendations of DBR (Barab & Squire, 2004)

It is important to consider that Co-CreARGBL is intended to be a method that guides a *long* process. This indicated that the process duration is expected to be measured in months. This will allow more professional complex games. Also, the process is not meant to be a one-shot rapid or automated process. Rather, the process is expected to include the design creativity of the participants. This approach is called *craftsmanship* in this thesis. Finally the method's intention is to create a guide that relates people around the design mediating by *dialogue* among the participants.

4.2.2 ROLES

Roles in the Co-CreARGBL method are taken from both, the roles used while in the field study working with the teachers and the roles found recommended in the literature review. The definitions and activities proposed for Co-CreARGBL are based on the Six-facets of Serious games proposed by Marne, Wisdom, Huynh-Kim-Bang and Labat (2012) as this model proposes that teachers and designers have different abilities that allow them to perform better in the facets of a game for learning. Those facets include: Pedagogical Objectives, Conditions of Use, Decorum, Problems and Progressions, Interactions and Domain Simulations. While the facets are not explicit in the models, the roles defined in the method act on the corresponding facets as participants work collaboratively in the design.

The roles proposed in Co-CreARGBL method are as follows:

- **The Leader:** They are in charge of initiating, managing and ending the process. Their role is that of a manager; but aside from that, they are called to be inspirers. Leaders will be in contact with Teachers and schools and they account for the quality of the final product. This is an important aspect to note, since while ideas and designs come from Teachers and Designers, Teachers are not responsible for the final quality of the product, as Co-Design is not a fully democratic process (cf. Roschelle & Penuel, 2006). As Penuel et al. (2007) suggest, the Co-Design process should start by a bootstrapping event (e.g. a short-course) to call Teachers to action. Thus, the Leader is in charge of managing and conducting that event. Teachers should be familiar with AR and GBL design as to be able to guide the team and the relationships with Teachers.
- **The Designers:** They are professionals in Game Design and/or AR. Their main activity includes scaffolding the ideas, documents, mechanics and other game elements that the Teachers propose. "Scaffolding" is used in the sense used by Co-Design researchers (Carroll et al., 2000; Cober et al., 2015; Melonio, 2013; Sanders & Stappers, 2008). Scaffolding means that the Designers help, guide, correct and make suggestions on the designs and concepts proposed by Teachers. This is necessary since as shown in previous experiences (All et al., 2012; Cober et al., 2015; Penuel et al., 2007) too much liberty on the design process can lead to Teachers (or Students) to propose too traditional solutions, unreachable solutions, or solutions that don't make use of the technology available. For the case or ARGBL, absence of scaffolding may lead the teachers to propose: games that are simple quiz-like games, AAA (commercial high-quality) games outside of any attainable funding, games that do not even make use of the device's AR potential (such as the use of cameras and GPSs), or games that ignore the potential to leverage contextualized and situated learning. Also the role of Designers includes helping the Teachers to convey ideas, proposing mechanics and other elements and constructing a Game Design Document that will be helpful for the Developers. Designers evaluate the prototypes proposed by Teachers in terms of rules and gameplay and check their suitability to start development.
- **The Developers:** Developers are in charge of constructing the final product based on the designs and proposals of Designers and Teachers. Developers are professional game and AR producers. This role can be fulfilled by programmers and artists, for example. Developers write code and build the required assets of the resulting software and hardware. Developers are encouraged to participate in the design sessions in order to be aware of the actual desires of the Teachers. Since most Teachers will not be great designers and their designs may not be self-explanatory, Developers should accompany Teachers and Designers in the designing process.
- **The Researchers:** Researchers propose the research design associated to the Co-Creation process. They know about research methodologies and DBR, so they are able to design the processes that lead to test the designs in natural learning environments. Researchers are interested in looking for the best ARGBL designs, design methods and frameworks that can be used by the Co-Design team to create and evaluate the artifacts. They are also interested in evaluating the process and the product as well and often they will report on observations during the process. Co-Design processes – much like Design-Based Research processes (Barab & Squire, 2004) blur the line that divides the role of Designers and Researchers (Sanders & Stappers, 2008). Researchers are in charge of building theories to explain their observed phenomena and design guidelines observing the process of design and evaluation. Those theories and guidelines will be useful for future ARGBL projects.
- **The Teachers:** They are the corner stone of the process, and while Students can be designers as well, this method is interested in gaining insights into Teachers as they plan their curriculum and classroom experience. Teachers will propose the main learning objectives and the main dynamics of the game according to the curriculum. They will also propose paper prototypes (Fullerton, 2008a) and Design Documents (Fullerton, 2008b) that convey the idea. Teachers are in charge of creating what they feel able to create. For example, while not many teachers will be able to code software many of them will be prone to draw illustrations,

provide maps and write character's dialogs. All of these assets should be concreted in a Game Design Document to be used by developers. Teachers have a special role in Co-CreARGBL. They create the game mechanics by thinking in terms of board games. They also get training in AR, so they can understand how to "augment" real elements into digital objects. This is the true value of ARGBL Co-Designing of games, because ARGBL games allow Teachers and Designers to collaborate by joining the feasibility and flexibility of the real world (which teachers are used to work) with the digital augmentation.

- **The Students:** Students can participate in the process of designing the ARGBL experience. And they are called to be game testers and the learners. Students are the ultimate user and their desires should be taken into account by Teachers and Designers. Due to this, students are of particular relevance in the process of evaluating the game, because the ability of the game to incorporate learning content and to motivate into the themes of the game should be reflected in the students' actions and outcomes during the learning session with the game.

Each Co-Design team may need other roles adequate to the particular aspects of their endeavor or to particular needs on the context where the game is planned to be implemented.

As can be seen, these roles come from a reflection on the literature findings, but also from this thesis' authors own experience with teachers in the field study. These roles have to be clear from the beginning as suggested by the Co-Design definition used (Penuel et al., 2007).

4.2.3 STAGES AND ACTIVITIES

Here the stages and activities that Co-CreARGBL suggests are defined. Stages represent the phases in which Teachers and Designers work together with a particular objective. Figure 26 shows a general schematic of the process.

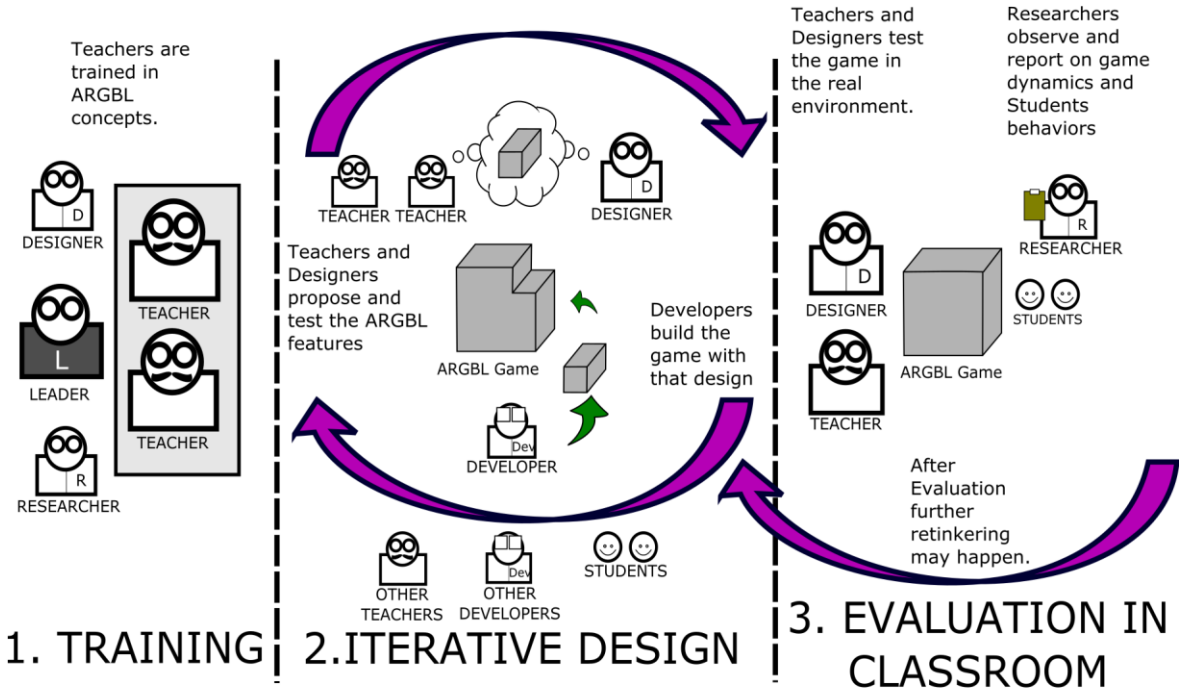


Figure 26 Stages in the Co-CreARGBL method.

Co-CreARGBL defines a set of activities for each stage. For each activity, there are a series of important considerations Leaders have to take into account. These considerations are fundamental to the application of the method. In Figure 27 the stages and their corresponding activities are shown. Considerations are shown in dashes boxes, meaning that while it is proposed here that they have to be taken into account, the actual models, frameworks, techniques and other considerations, have to be selected and studied by the Leaders and Designers who use the method. For each consideration some items found in the literature are suggested. It is noteworthy, that the particular aspects of the considerations should be well understood by the Leaders and Designers, and thus, the actual choice is exclusive for them.

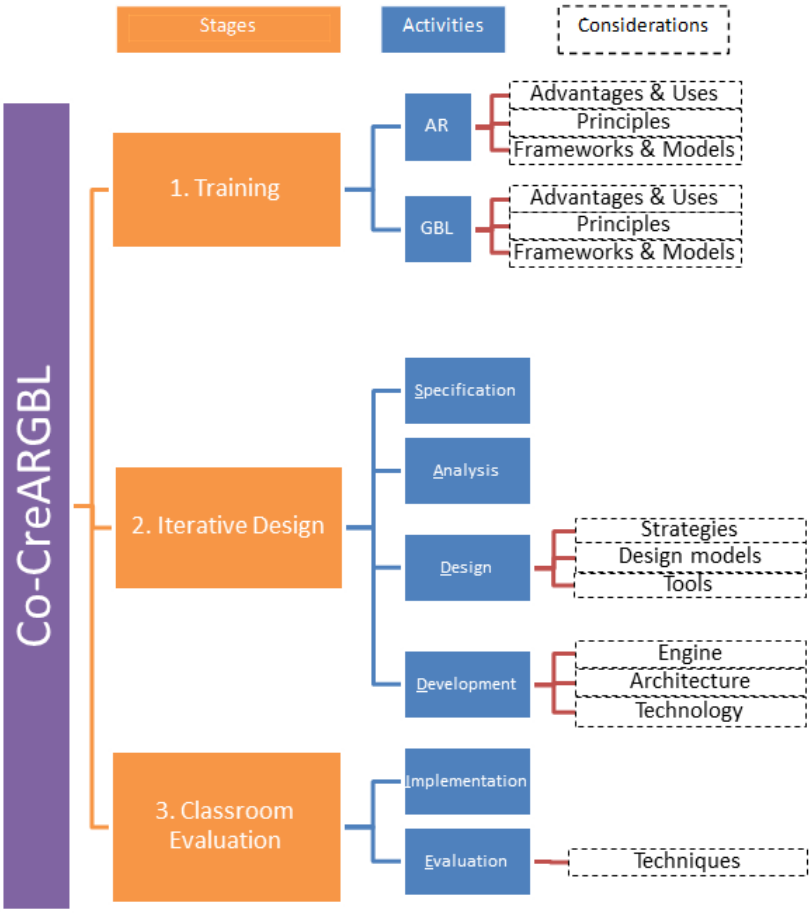


Figure 27. The Co-CreARGBL Method. Considerations are showed in dashed boxes because the actual implementations of them have to be selected by users.

Stages and activities mentioning considerations proposed by Co-CreARGBL are:

TRAINING

Unlike most methods of Co-Designing educational resources, Co-CreARGBL considers training a fundamental part of the process. Since AR and GBL are quite unknown technologies and approaches to most Teachers, Leaders have to take special care into introducing these two concepts to Teachers, in order for them to understand the potentialities and benefits of using them in the classroom. This was supported from the field study and the exploratory scenario.

The training stage has two activities, one activity for each one of the aspects of the method (AR and GBL). The **AR** and the **GBL** training should be performed in sessions apart and on one of those there should be a session involving both at the same time (ARGBL).

The activities of this stage are:

- **AR:** Teachers are most likely not familiarized with AR. Thus, Leaders and Designer must introduce the concepts of AR applied to learning to teachers. In this activity it is important that Teachers experiment AR by themselves. So it is necessary that the training involves actual devices and example applications for learning. So many can be found in the applications stores of Android and IOS, so that should not be a problem. Leaders should convey the idea of AR benefits to Teachers, so it is useful to base the training in scholar findings. These are the considerations for this activity:

    - ***Advantages & Uses***: In literature there are many studies that have studied the advantages and uses of AR for learning. Leaders should pick one of them, just to not override Teachers with too many which could be confusing. For the uses, Leaders can include Yuen's five directions (2011) along with Diegmann's et al. (2015) revision mentioning engagement, motivation and real world experiences, collaboration and creativity; Bitter and Corral's considerations (2014); or Sheng, Xia and Li's applications of AR to learning (2014) that include AR-Reading, Location-Based Learning, Object Modeling and Skill training . The work of Santos et al. (2014) conveys three advantages of AR in learning which include: real world annotations, contextual and vision-haptic visualization; Finally, Bacca et al. (2014) compile a set of advantages reported by AR applications to learning which include increased understanding and collaboration. Readers are encouraged to check on these references for further details.

    - ***Principles****:* Teachers should understand their role as Co-Designers. Thus, it is smart to guide them with the use of principles. The most straightforward principles suggested are those depicted in the work of Cuendet (2013). However, Santos (2014) describes AR applied based on Multimedia Theory which can appeal more to Teachers. Teachers can also convey the principles compiled by Dunleavy (2013) while having in mind these apply mostly to Location-Based AR. These principles are Challenge, Fantasy and Curiosity.

    - ***Frameworks and Models****:* Once Teachers agree on the benefits of AR applied to learning, Leaders should introduce some guiding framework or model that helps to understand AR applications. Our classification of AR applications shown in chapter 2 can help. Leaders should introduce the different types of AR and their affordances (Cheng & Tsai, 2012) and name the concepts they will be using as designers, like: markers, tracking, devices and so on.

- **GBL:** In general, Teachers do agree on the benefits of games and playful learning in the classroom. Nonetheless, there is still a need for training in the benefits of GBL and what makes a game useful for learning. In this sense, it should be useful that teachers become gamers during the training stage. Also, they should be free to play in the training sessions, while conducting a process of reflection to make them re-think the process of learning (Gee, 2003). The considerations to have in mind are:

    - ***Advantages & Uses****:* It is recommended to start by explaining Steinkuehler and Squire's (2014) four uses of Games for Learning which include Games as "bait" for learning, as vehicles of content, as architectures for engagement and as evaluation. And for the advantages, Leaders can use either the works of Prensky (2004, 2005a) or the advantages depicted in (Gee, 2005b) which include Learning, Understanding, Meaning and Problem-Solving.

- ***Principles***: Once Teachers understand the advantages of the use of games for learning, they should understand principles to design good Games for Learning. In this sense, we strongly recommend the 5 properties of good Games for Learning by James Paul Gee (Gee, 2009) that define a good Game for Learning is a game that allows to take advantage on rules to attain goals, microcontrol game components, uses models, offers experiences and allows players to live their own trajectory .

- ***Frameworks and Models***. There are several frameworks and models proposed to understand, analyze and design Games for Learning and serious games. Have in mind that using more than one can be confusing to teachers. So users of the method should pick one, understand it and compromise with it. Notable examples include the one used in the validation of this method, which is called ATMSG (Carvalho et al., 2015); the GREM model if users plan to create a game based on scenarios, elements and rules (Zarraonandia et al., 2014); Marchiori et al.'s metaphor for narrative games (Marchiori et al., 2012); Social games models like Cosmodel (H. Tobar-Muñoz et al., 2011) or the six-facets model as explained above (Marne et al., 2012). The models and frameworks often apply to a small sub-set of games for learning, thus, Leaders and Designers should reflect on which one apply and if the design context is suitable for a particular model.

After these activities, teachers should be aware of the characteristics of AR and GBL for learning. Note that these activities have treated AR and GBL as concepts apart, so a session considering ARGBL as a newer term that brings aspect of both approaches is recommended.

During the ARGBL sessions the Instructors should convey the idea that ARGBL could consist of an AR application with learning objectives, but with a game-like structure to organize the learning and playing activity; or, the Instructors may convey the idea that ARGBL consists in adding to a game for learning a novel form of interaction with the real world that includes AR characteristics.

To help on this we propose the continuum shown in Figure 28. In this continuum, ARGBL games are classified according to the level of Reality and Virtuality that they present, similar to the Mixed Reality continuum proposed by Milgram and Kishino (Milgram & Kishino, 1994). This continuum applied to Image-Based AR games that are often played with physical pieces of printed material.

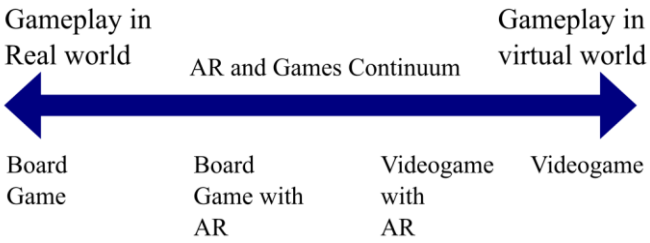


Figure 28. Continuum depicting 4 ways of mixing Games and AR

The continuum shows four ways of mixing Games and AR according to where the gameplay takes place. In Games involving some kind of AR, the gameplay can occur in the real world (e.g. moving pieces and cards) or in the virtual world (Clicking, or Touch-Gesturing virtual elements). This said we can identify 4 types of games going from one extreme of the continuum to the other:

- **Board Game:** In board games like *Chess, Monopoly, Settlers of Catan, etc.* action occurs in the only realm it can happen: in the real world.

- **Board Game with AR:** AR can give a layer of digitally-augmented elements that affect the gaming experience. In this type of game, the gameplay occurs *mostly* in the real world, allowing social interaction among players and interaction with real objects. However, use of AR enriches the experience by providing a layer of interaction, structure, graphics or information that cannot be found in the real world. An example of a Board Game with AR is "*Invizimals Desafío X-tractor"* (Borras, 2016).
- **Videogame with AR:** In Videogames with AR the gameplay occurs *mostly* in the virtual world (i.e. in the display device). While there is an interaction with real elements, in this type of game, this action is often simple and most attention goes into the augmented elements. An example of this is "*Fetch Lunch Rush!"*(PBSKids, 2012).
- **Videogame:** In Videogames all the action occurs in the virtual world not involving the real world at all.

ITERATIVE DESIGN

In this stage, although is called "design", Teachers and Designers work hand-on-hand to deliver a final product, not only to ideate it. This product should be an ARGBL game where ideas and main designs are proposed by Teachers, while Designers scaffold them. Developers are in charge of introducing the changes to the game being built (see Figure 26). Activities in this stage start the first four phases of the SADDIE process (Zapušek & Rugelj, 2014) with special care on the Design (D) activity which is central to the process and has special aspects. To help in the proposition of the ARGBL game idea, Co-CreARGBL proposes a "Framework for Proposing the ARGBL game Idea" which consists in a set of canvases that Teachers and Designer use to come up with the elements that should be included in the ARGBL experience. Those elements include important aspects of both the Game and the AR part; all of them based on constructs found in the literature.

Put special emphasis on the "Iterative" feature of this stage. From the field study experience, Teachers do not propose ideas according to the principles of ARGBL from the beginning. Just after the training stage, most of them will propose "pseudo-games" where the mechanic is only answering to questions that some character has talked about before. This is not desirable because it underuses the potential of games. Much like in Penuel's experience (Penuel et al., 2007), where teachers only proposed ideas that were not in line with the new pedagogical approach that researchers where looking for; in Co-Design of games for learning something similar happens. Thus, scaffolding and guiding the Teacher's ideas is central to Co-CreARGBL.

- **Specification (S):** In this activity Teachers reflect on learning issues they may have in a subject in the classroom. Then, Teachers identify and select the learning objective they will be aiming with the use of a game with AR. While this can be pretty much anything, Designers should help in this decision because not every game and technology apply to any subject matter, and not every subject matter has a favorable tool in games. In this activity Teachers propose, identify, or create a set of learning materials that will be the base for the game. The outcome of this activity is a document stating the ***Learning Objective*** of the game, and the ***Learning Materials*** to be used.
- **Analysis (A):** In this activity Teachers and Designers analyze the learning objectives and the learning materials trying to come up with an idea of an ARGBL game. Co-CreARGBL suggests to reject the idea of simple "flashcards games" (see Klopfer et al., 2009) and prefer complex games that represent the "game behind the content" (Squire, 2011b). The outcome of this activity is a document stating the main idea of the game and the ***Game Objective***, depicting the objective of the player, and the ***conditions for winning, losing and ending the game***. Often, Teachers define these objectives and conditions very easily, especially when giving examples and analogies to board games.
- **Design (D):** This is perhaps the most important activity teacher-wise. In this activity Teachers, Designers and Developers work along to define the elements of the game. Elements of the game include the design of mechanics, interfaces and content. Also, details should be specified for game objects such as physical elements and digital assets. Researchers use the assets

generated by Teachers and Designers as data for the corresponding analysis. Considerations on this activity include:

- ***Strategies**:* A good start should be the desired emotional effects on the players as explained by the "aesthetics" followed by the "dynamics" in (Hunicke, LeBlanc, & Zubek, 2004). Then, when the desired outcomes are defined work can start on the actual "mechanics" (game elements, actions, rules) that the game will have. Then, Teachers and Designers start brainstorming sessions (Kultima & Paavilainen, 2007) which previous Co-Design studies have shown to be the most effective way teachers communicate (All et al., 2012; Carroll et al., 2000; Cober et al., 2015; Muller, 2009; Van Rosmalen, Boon, Bitter-Rijpkema, Sie, & Sloep, 2014; Zainuddin, 2010)
  The mechanics defined are portrayed using a **Paper Prototype** as defined by Fullerton (2008a). This prototype is built using simple elements easily found by Teachers such as*:* cardboard, paper, scissors, dice, and so on. Teachers are more comfortable working from the physical part of the ARGBL game. As shown in Figure 29, they express their ideas in terms of board games and similar landscapes, while professional designers scaffold those ideas in terms of digital elements. Designers and Teachers alike propose the main AR interaction and how it will be useful to the game and the learning activity. Finally, the game's mechanics are concreted in a **Design Documents** which feeds the game development activity.
- ***Design Models**:* Design models are guidelines and principles that guide the design activity. Although, as have been said, Designers should compromise with only one as to make it easier to follow by Teachers. Suggestions include the same design models mentioned in the training stage.
- ***Tools***: While tools regarding the creation of the prototype include pieces, dice and other simple elements, the tools to create a collaboratively-composed design document should be virtual collaborative tools. This is especially important if teachers and design teams are geographically separated, thus, virtual editors come in handy to coordinate the work. For example, simple online tools like *Google Docs* or *Dropbox Paper* are recommended. However, in the end, Designers and Teachers should use the tool they feel the most comfortable with.

- **Development (Dev):** The development activity includes the whole software coding and developing activity. While this activity is in charge of the Developer, Designers guide the process and Teachers accompany by checking periodically on digital prototypes (Fullerton, 2008a). Developers choose the *Engine, Architecture* and *Technologies* to use. None are strongly recommended here because these highly depend on the particular designs.

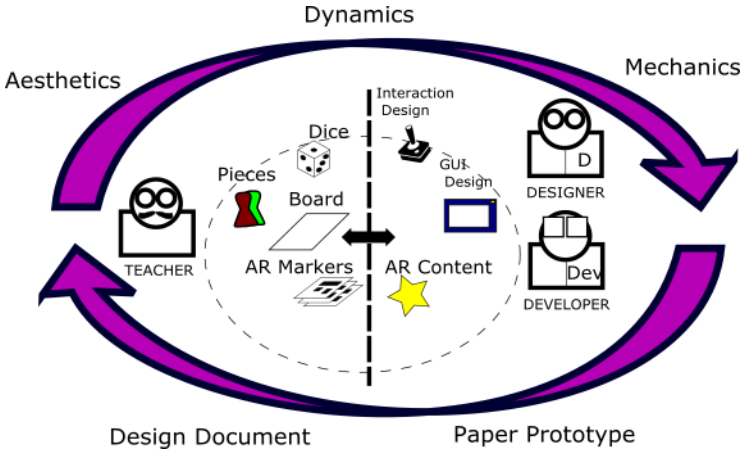


Figure 29. The Design Activity in Co-CreARGBL

Framework for Proposing the ARGBL game Idea

To support the *Specification, Analysis* and *Design* activities a "Framework for Proposing the ARGBL game idea" is proposed by Co-CreARGBL. The framework consists in a series of templates that include the main considerations that Teachers and Designers should have when defining the game concept. The templates are printed in a big format, so teachers are able to write their ideas onto them. This is meant to be used during the first Brainstorming sessions. It also, works with a set of sticky notes, where teachers write their ideas and other information as requested by each of the templates. The final goal of this framework is to generate a game concept refined. All of the concepts in the framework are taken from relevant design models in the literature.

The framework proposes three steps: Recognizing the Learning Objective, Ideating the game and Refining the Idea. The following is a brief description of each of the steps. Here, the steps are described; the actual templates used are shown in big format in Appendix C. The accompanying website includes printable versions of the templates in English and Spanish.

- **Step 1: Recognizing the Learning Objective:** The main goal of this step is to identify and select a learning objective.
    - **Step 1a:** During this step Teachers propose a general objective followed by minor, more concrete learning objectives. The template asks the teachers to propose the contents, concepts, values and skills that they want to transfer to the students.
    - **Step 1b:** The template asks the Teachers to define the Aesthetics and expected Dynamics of the game (what is the student looking for when playing the game at the emotional level). This was done following the recommendations from the MDA model for games (Hunicke et al., 2004). The template also asks for the definition of the player characteristics and their context. This can be done using a *Persona*[11] as a design profile. This was done because, Players and context are a fundamental part of a game as defined in the theory of game elements (Järvinen, 2008)
- **Step 2: Ideating the game:** In this step, Teachers and Designers brainstorm the idea using the templates.
    - **Step 2a:** The brainstorming session is guided by the template. The template shows the elements that should be defined for the ARGBL game, namely AR elements, environment, components etc. The Teachers and Designers use the Post-it to propose ideas for each of the elements. In this step, the Teachers and Designers include ideas that answer the design questions of the template.
    - **Step 2b:** A process of reflection and presentation is done with the ideas of the Teachers.
    - **Step 2c:** Teachers use the ideas placed in the post-its and reorganize them in the items defined by the template. The items on the template define the most important elements of the ARGBL game including the AR elements, use of the technology, art, and story among others.
- **Refining the Idea:** In this step the Teachers collaborate to merge the concepts proposed in the previous steps and propose an initial game idea that will be used as the first concept to be used in the process guided by Co-CreARGBL.
    - **Step 3a:** Teachers and Designers answer a set of questions proposed by the template, using the structuring of the idea made in the previous steps.
    - **Step 3b:** Teachers and Designers reflect on the proposed idea by answering a set of questions that account for the quality of the game idea as a game for learning. This questions are based on the principles defined by (Gee, 2009)

[11] In User Experience Design, a *Persona* is the profile of a fictional person that represents the typical user of the system

- **Step 3c:** Teachers and Designers re-state the game concept based on the reflection on the previous step.
- **Step 3d:** Teachers and Designers fill the information of the game as stated in the template.

The use of the framework is not mandatory as teams can found other ways to propose ideas and concepts. However, it is strongly recommended because it guides the creative process; particularly it helps Teachers to think in the elements of the game.

EVALUATION IN CLASSROOM

In this stage the product created in the previous stage is tested in a classroom (a naturalistic environment) with real Students. The objective of the stage is not to test Students' knowledge or learning (although this can be used as a technique) but to test the behavior of the product in a learning environment. This stage has two activities:

- **Implementation (I):** It involves the deployment of the product in the learning environment. Typical implementations include the recognition of the learning environment and its resources. Leaders and Designers prepare the devices and the physical elements (boards, markers, etc.) to be used with the game. Teachers prepare an instructional activity (see Carvalho et al., 2015) to be administered along the game. The outcome of this activity prepares a scenario to perform evaluation.

- **Evaluation (E):** In this activity researchers plan and perform observations on the development of the learning and playing activity (Carvalho et al., 2015). *Techniques* to use to perform these observation should report on what is the general performance of the game, how players feel during the playing and learning activity and what technical changes should be done to the product. *Field Observations* are suggested to record the interaction. It is important to conduct *de-briefing* interviews with teachers and students (Cober et al., 2015; Melonio, 2013).

4.2.4 RECOMMENDATIONS

Here some recommendations are shown based on the observations on the field study and its validation. Users of the method are encouraged to apply these recommendations for the sake of the project.

- Teachers should be encouraged to be ARGBL designers and not only "informers". Thus, teachers should play and use AR applications and then reflect on them and their uses and advantages to learning.
- Most Teachers are not gamers. A library of game components and styles related to learning objectives is useful for them when designing mechanics. Carvalho et al. (Carvalho et al., 2015) propose a taxonomy of game components. Prensky (2001a) proposes a list of types of learning related to game styles.
- Teaching is to be considered as a design endeavor. Teachers should be encouraged to feel themselves as crafters and artificers whose art includes educational experiences.
- Most Teachers will start by proposing fact-based games, where AR and Games are just shallowly used. Teachers should be encouraged to prefer an experiential learning approach rather than just notional learning.
- Participation is the key. Teachers should be encouraged to participate as most as possible. The participatory model proposed by Santos et al. (2013) can be used as a framework to achieve this.
- The ARGBL game should promote discovery and reflection. Designers should reject or scaffold ideas that do not show these ideas prominently.

- AR and GBL are often used in *Inquiry–Based Learning* strategies (Gee, 2008b; Jerry & Aaron, 2010; Squire & Jan, 2007) that offer experiences based on the discovery, inquiry and general curiosity of the learner. Teachers should take advantage on this and propose a design that promotes inquiry and reflection on the learner.
- Teachers are quite shy at the beginning of design sessions. Brainstorming can also serve as an ice-breaker (All et al., 2012).

It important to recognize that following a method like Co-CreARGBL has associated difficulties and costs because, as in any collaborative endeavor, the requirement of coordinating people, gatherings, resources and other elements is not an easy task. Some teams will indeed have problems in fulfilling the roles with people with the required abilities, or following the stages and activities at their full potential. This said, some reflections and recommendations are listed here in order to circumvent these difficulties and costs with teams not able to comply with every aspect of the method:

- The Leader role may (and it is recommended to) be filled by a Designer or by Teacher. This way, the team will not only have a manager but a design or teaching savvy person that will know about the details of the ARGBL experience being created. Also, this helps the team to need less people to start the work.
- Often Designers start these kinds of processes. Most schools will be happy to collaborate in the process by allowing Teachers to help and form part of the Co-Design team. Designers and Leaders are advised to approach schools, especially those with Teachers that are trained in creative endeavors.
- If Teachers start a process of Co-Design, they will not have access to design and development professionals. However, universities, and other educational and research facilities may provide consulting on design. While this is not ideal, if Teachers are not able to form a Collaborative team, they may rely on advice from professionals in the field.
- In Teams where Teachers cannot find programmers, or artists, many authoring tools and easy-to-use design tools are available on the internet. Readers may consult the authoring tools described in chapter 2. However, this is not ideal, because that way, the team will be constrained to the capabilities of the tool.
- The Researcher role is optional if the Team is not interested in going further that the development of the educational experience.

4.3 CONCLUSIONS OF THE CHAPTER

Since AR and GBL are being proposed as tools and approaches to be included in the classroom for learning purposes, more and more designs are to be created. In this thesis we are proposing the use of AR and GBL experiences joined (dubbing them, ARGBL). The exploratory scenario showed the advantages and implications of using ARGBL and it gained interest in teachers; it also showed the need to include teachers in the design process. Thus, since there is a need to create ARGBL games as learning resources, but Teachers lack the expertise to create such artifacts and professional Designers find valuable help in Teachers, a Co-Designing approach named Co-CreARGBL to create ARGBL games for learning is defined in this chapter. In this chapter, Co-Design has been portrayed as an answer to the increasing need of using newer technologies and experiences in the classroom as it alleviates the burden of building software from the teacher, while allowing designers to achieve a deeper connection with the educational contexts they are designing to.

In this chapter, Co-CreARGBL has been introduced as a method for the Co-Design of ARGBL games with Teachers, considering teachers not merely as informers but as designers themselves. Co-CreARGBL includes a set of stages and activities that are proposed based on theoretical findings and personal experience from the field study conducted. These stages are organizes in a hierarchy where stages include activities and the activities have considerations that have to be taken into account by the team using the method. Co-CreARGBL proposes three stages: Training, Iterative Design and Evaluation in

Classroom; each with their own activities. The activities embedded into the stages follow the pattern of the classical approach of ADDIE (Branch, 2010) but include an additional activity at the beginning named *Specification* as suggested by previous studies (Rugelj, 2015; Zapušek & Rugelj, 2014). This chapter has also suggested recommendations to the considerations of each activity. The recommendations are rooted in existing literature.

The Co-CreARGBL approach was validated within the same field study. The validation of the method was done by inviting Teachers to participate in the process of Co-Designing ARGBL games and experiences. The roles, stages and activities of the method were enacted and the researcher compiled data as to validate the method. This validation process is shown in the next chapters.

5 APPLICATION OF THE METHOD: TWO CASE STUDIES

Co-CreARGBL has been introduced as a method to Co-Design ARGBL games and experiences with Teachers. In order to validate the method two case studies were conducted. The case studies involved Teachers and Designers alike who participated by designing, implementing and evaluating an ARGBL game and an accompanying experience. The whole process took several months and ended after the evaluation of the corresponding products in a "naturalistic" setting (a class in a classroom) with students.

The validation process was designed from the beginning aiming to evaluate the efficacy of the method and the results it produced. The validation was performed under the recommendation and structure of the Validation Square Framework (Pedersen, Bailey, Allen, & Mistree, 2000; Seepersad et al., 2006) which proposes a set of Validities and Acceptance Conditions in order to accept the method as valid. The validation method, performed under the Validation Square, was done performing a long process of observations and recording the participation of the Teachers and the design team.

These observations were used as arguments for the validation. From the observation four attributes of the process were analyzed:

- **Attribute of "Completion"**: The actors of the process perform the proposed stages, activities, and tasks of Co-CreARGBL method.
- **Attribute of "Quality of the product"**: The resulting product has quality, this is observed under two perspectives:
    - Students' perspective: The resulting product is benefic for the Students in terms of learning and motivation.

    - Peer-Teachers' perspective: The resulting product has quality according to the judgment by Peer-Teachers.
- **Attribute of "Satisfaction of the Teachers"**: Teachers show satisfied with the process and the results.
- **Attribute of "Comprehension by the Teachers":** Teachers comprehend the parts of the process.

For the validation of the method, the two case studies comprised a set of Teachers from elementary schools in the department of Cauca in Colombia. The Teachers were part of a bigger set of teachers participating on a local teacher-development program called "Maestros Creativos" (Creative Teachers, in Spanish) sponsored by a local NGO and the local government. A call was done in order to invite teachers to participate in a training process (conducted under the terms and considerations of the Co-CreARGBL method). A total of 50 teachers subscribed to the training process.

A Pre-Survey was conducted on the 50 teachers in order to gain information about their knowledge and experience using AR and Games for Learning. The Pre-Survey included five questions, regarding the experience of the teachers with digital and analogical didactics tools (playful activities, board games, digital games, 3D objects and AR). The Pre-Survey also asked for exampled of the tools when the teachers manifested experience with them and other open questions regarding their opinion about the use of games and technologies for teaching. Figure 30 shows a summary of the answers the teachers gave.

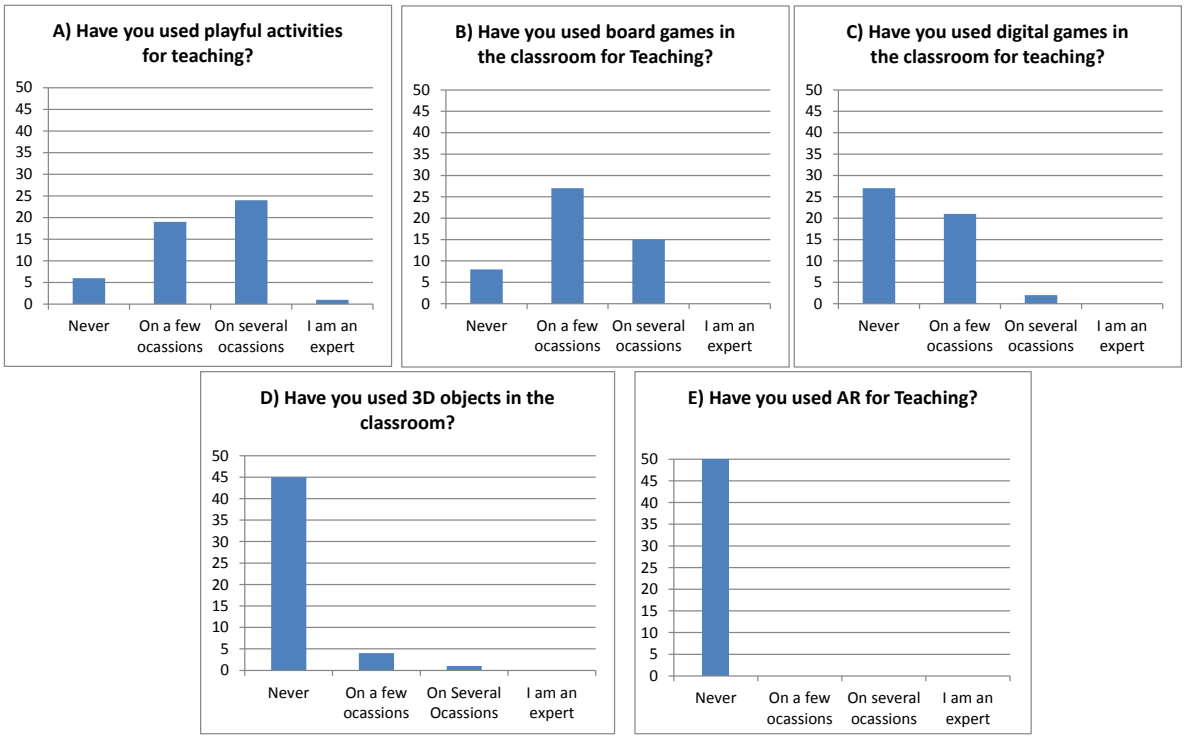


Figure 30. Results of Pre-survey on Teachers Participating in the ARGBL Training Program.

It is easy to recognize from these results that while teachers use playful strategies in the classroom (A) such as board games (B), they are not familiar with digital games (C),3D Objects (D), or AR for learning (E). Moreover, when asked what kinds of playful activities they used with their students, most teachers answered with: simple rhymes, traditional songs from the local region and simple board games like *Snakes and Ladders* or Pair-up games. Notice also, how most teachers have not used digital games and those who had used them refer to simple free online games like Pair-up games and flashcard games

(see Appendix D). Nonetheless, when teachers were asked whether they consider games to be useful for the learning environment or not, most of them answered positively by remarking the capabilities of games of transforming the learning process and motivating students.

Other results from the survey are shown in Appendix D such as statistics about the grades attended by them, the areas taught and the categories of the reported playful activities used. The raw answers of the Teachers can be found in the accompanying website.

On the other hand, regarding AR, most teachers answered on the Pre-Survey that this was the first time they had heard of the concept, and while they showed eager to learn about it, most of them felt they were new to it.

The teachers were invited to participate in the creative process of designing a game for learning using AR. Six teachers from the original 50 answered to the call and those formed the group of teachers participating in the case study.

The six teachers were grouped into two teams. The first one will be called here "Team A" and the second one "Team B". Teachers in both teams received the corresponding training and they conducted separately two projects with different learning objectives. Teams were arranged by the teachers. The reasons for this arrangement were mainly due to teachers living and working near each other.

The teams were arranged as follows: Team A had four teachers from a school in the Timbio Municipality and one from Popayán, the capital of the department. The two teachers belonging to Team B were from a school in the Caldono municipality. Both teams were Co-Design teams, and as such they included teachers and professionals in AR and GBL as participants.

In this chapter the two case studies are described. This includes the case studies experiences, the teachers and designers who participated and the roles they performed during the process. This chapter shows, for each team, the timeline that describes the undertaken process detailing each stage and activity performed under the Co-CreARGBL method. Also, this chapter explains the specific considerations used as proposed by the Co-CreARGBL method, while on chapter 6 the validation process is detailed with its corresponding results and analysis of the results.

5.1 DESCRIPTION OF TEAM A'S WORK: AN ARGBL EXPERIENCE ON GEOGRAPHY AND SOCIAL SCIENCES

In Team A, four teachers participated by fulfilling the role of *Teacher* as suggested by the Co-CreARGBL method. The teachers' characteristics as taken from the initial survey are presented below. Teachers are not noted by name but by a code in order to keep anonymity:

Table 11. Characteristics of the Teachers on Team A

Teacher	**Subjects Taught**	**Courses**	**Have you used…**				
			Playful Activities	**Board Games**	**Digital Games**	**3D Objects**	**AR**
TA1	English	Middle and High School	On several occasions	On a few occasions	On a few occasions	Never	Never
TA2	All	1st grade	On several occasions	On several occasions	Never	Never	Never
TA3	Spanish	4th grade	On a few occasions	On a few occasions	Never	Never	Never
TA4	Social Sciences	9th grade	Never	Never	Never	Never	Never

As it can be seen, most Teachers had used playful activities and board games for teaching, just one had used digital games and all of the teachers in Team A where not familiar with 3D objects and AR. Thus, this remarks the importance of the training process previous to conduct the process of Co-Design. Also, teachers in Team A report having used playful activities on a few or several occasions. Regarding these playful activities, teachers reported to have used activities such as *Role-Playing games* (The interpretative activity not the videogame genre), *memory games* and *nursery rhymes*. Some teachers reported having used board games, but as in the general case, these games were limited to simple *roll-and-move* games and basic games such as *Bingo, Crosswords, Alphabet Soup* and others that would not classify as board games like *Origami* (Papiroflexia) sessions.

While teachers came from different background, all of them agreed to work on a defined learning objective of the game, independent from their regular subjects.

As for the professionals in AR and GBL participating in Team A, their roles were defined from the beginning of the experience according to Co-CreARGBL method. The roles were fulfilled as follows:

Table 12. Professionals in AR and GBL in Team A

Professional	Roles	Comments
PA1	*Leader, (Head) Designer, Researcher*	This participant refers to the main author
PA2	*Leader*	This participant acted as assistant and was the main contact with schools, teachers and students in the city
PA3	*Developer*	This participant acted as programmer
PA4	*Developer*	This participant acted as programmer

The team agreed on using as the main mean of communication a *Google Group,* files were shared via *Google Drive* and *Dropbox* and weekly design meetings were conducted to advance on the design, perform observations on prototypes, plan evaluations and so on.

When roles were cleared and the main objective of the process was declared (to create an ARGBL game and accompanying experience aiming towards a defined learning objective) then the work with team A started. Figure 31 shows the timeline of the process depicting from the beginning of the Training stage until the final of the Evaluation in Classroom stage as defined by Co-CreARGBL.

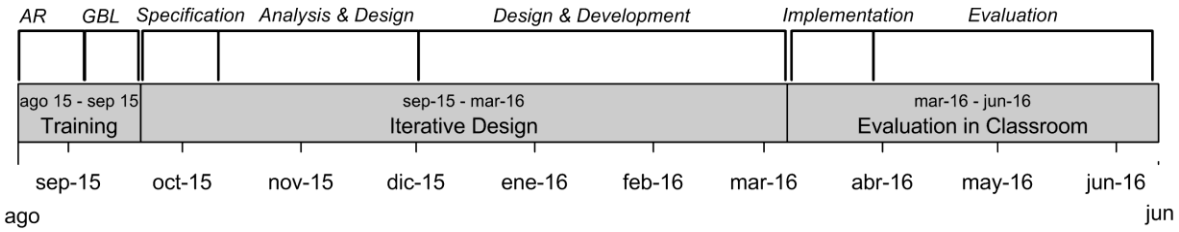


Figure 31. Timeline of Work with Team A

Next, each stage of the process is briefly commented. These comments are a summary of the most important events that happened during the execution of the project and are based on a set of field notes taken weekly. The field notes can be found in the accompanying website.

TRAINING

With this set of teachers the training process began paying special attention on transmitting to the teachers the principles, advantages and uses of AR and GBL. The training was conducted in August and September of 2015 as the Figure 32 shows.

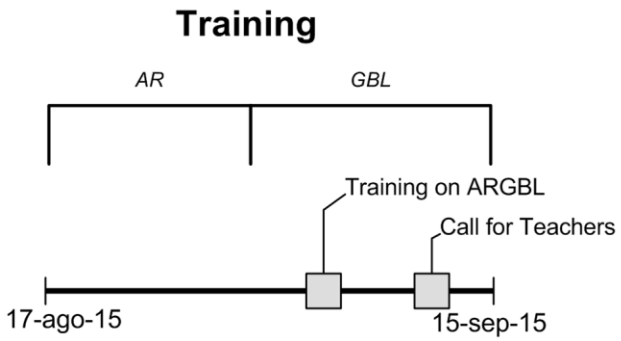


Figure 32. Timeline of the Training Stage with Team A

During in the training sessions, teachers were able to experiment with AR authoring tools such as *Aumentaty® Author and Viewer*, *Metaio® Creator*, AR applications from the *Google Play Store,* and a variety of games for learning as well. From the considerations proposed by Co-CreARGBL, for each activity these were used:

- **AR Activity**: Teachers participated on several sessions were they were tasked with the creation of simple AR learning objects using AR authoring tools. The considerations were:
    - **Advantages and Uses**: Teachers were trained in Yuen's five applications of AR (Yuen et al., 2011) and for the Benefits the compilation by Diegmann et al. (2015) and Bacca et al. (2014)were used.
    - **Principles**: Teachers were trained in the conclusions by Santos et al. (2014) and the principles for designing AR applications for Learning by Cuendet et al. (2013).
    - **Frameworks and Models**: None specific model was used aside from the classification of AR applications by Cheng and Tsai (2012).
- **GBL Activity**: Teachers used board games, digital games and ARGBL games during these sessions. They also designed and created simple games using the *Scratch™* block-programming environment. The considerations were:
    - **Advantages & Uses**: Teachers were trained in the advantages and the uses stated by Steinkuehler & Squire (Steinkuehler & Squire, 2014).
    - **Principles:** Teachers were trained in Gee's properties of games for learning (Gee, 2009)
    - **Frameworks and Models:** Teachers were introduced to the ATMSG model by Carvalho et al. (2015) and the library it proposes.

ITERATIVE DESIGN STAGE

The iterative design stage was started around the end of September 2015. During the first meeting the roles were defined and the Teachers accepted to participate as active designers and not only as informers. The design started based on a set of parameters which included only that the product to be designed should be an ARGBL game and an accompanying experience (implemented on an instructional activity) and the application of an evaluation instrument. The Figure 33 shows the timeline of this stage.

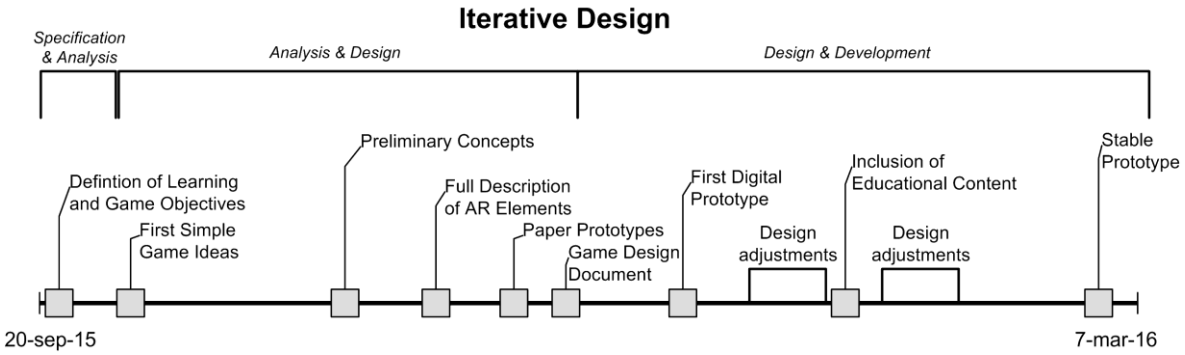


Figure 33. Timeline of Iterative Design with Team A

During the weekly meetings teachers participated on the activities proposed by Co-CreARGBL method and they accomplished tasks as stated by the Leaders of the project. The tasks were the selection of learning objectives, definition of mechanics, and definition of augmented objects among others. The tasks were stated during the meetings. However, they were re-stated on the Google Group for everyone to be aware of them. This strategy seemed to work, because teachers strived to accomplish the tasks as solicited and this was a way of leaving "homework" for teachers so they would be able to work during the week from home or the school and post the questions as needed.

Specification Activity: Early design meetings revolved around the selection of a learning objective. Teachers proposed several candidates to learning objectives mainly because their background and subjects were different as shown in Table 11. When teachers agreed on the learning objective referring to Social Sciences then they debated about what would be ideal that could be a needed on their classroom. They concluded that an actual need was the identification of the richness in their own department (Colombia is politically divided in departments). Thus, they wanted to "augment" the maps easily found in the classroom.

With this in mind, a set of educational content was drafted. These were mainly informational articles, data taken government sites and information from Wikipedia about the department and its municipalities.

Analysis Activity: While the specification activity was straightforward, the analysis activity was iterative in itself and often it was necessary to re-define some aspects of the Specification activity (In Figure 33 this is shown as intertwining both activities). This was mainly due to teachers proposing ideas that were just simple quiz-like games or simple memory games. The brainstorming sessions were conducted according to suggestions by Co-CreARGBL, however, due to the lack of experience of teachers with ARGBL, their ideas had to be "scaffolded" as suggested by the method.

In this sense, a set of more complex ideas were evolved from the initial ideas always trying to "look for the game behind the content" (Klopfer et al., 2009). After some design meetings iterating over the general idea, by later October 2015 the main idea was fleshed-out.

Teachers and Designers agreed on a game were the main premise was to conduct the Students around the department, by them playing the role of "Touristic guides" with the mission of taking visitors to their desired destinations over the augmented map. For this, teachers believed, students had to recognize the richness of the region as stated in the learning objective.

Design Activity: Weekly design meetings then focused in designing the actual parts of the game. Often it was necessary to redefine some aspects of Analysis and Design for example re-defining ideas or narrowing learning objectives and game goals (In Figure 33 Analysis and Design intertwine at the beginning of the Iterative Design stage). This process includes among others:

- **Definition of AR elements:** AR elements are a vital part of the ARGBL experience. Following the suggestions of the Co-CreARGBL method Teachers and Designers thought about the main augmentable elements to be found in the classroom, among which they selected the maps of the region. Other augmentable elements included marker for interaction and information retrieval. Teachers and Designers based their proposals on existing AR games such as *Fetch, Lunch Rush, Invizimals: Desafío X-Tractor* and others found in the literature (Borras, 2016; Kirak Kim, Park, Hong, & Jung, 2005; C. Kirner & Zorzal, 2006; PBSKids, 2012)
- **Mechanics design:** Teachers and Designers collaborated by brainstorming, proposing and testing mechanics ideas. The mechanics were drafted as preliminary concepts and they were related to the "Augmentable" elements in the game (such as the map). The main mechanic of the game is to traverse around the map and bring visitors to their destinations.
- **Paper Prototype design and testing:** Teachers and Designers constructed a small set of prototypes for the main idea and for the previous ideas as well. These were mainly printings of the markers-to-be images and some rules testing among the team.
- **Design Document writing:** When a prototype idea was accepted by the team, its details were then included in a set of Design Documents posted in the shared *Google Drive* folder. The creation of this documents took weeks, and Teachers collaborated by giving ideas, while not always by writing them themselves.
- **Adaptation of Learning Content:** Teachers and Designers devised a sub-system in the game allowing the students to retrieve information about the municipalities. This system was fed by the learning content proposed by the Teachers. As this content is of general use it was adapted to be used in the game. With this content, Teachers also proposed the creation of a notebook with the information to be used in the class.

Development Activity: By mid December 2015 an initial idea was already in place and Teachers left for holidays. Developers started creating Digital Prototypes that were checked by the Leaders and the Designers according to the designs stated. During the early days of this stage Teachers would not post on the *Google Group* nor communicate via email because they were on vacations.

After teachers returned from holidays, a series of weekly revisions and supervisions of the prototypes started (Figure 34). On average, every week developers showed an advance on the prototype and teachers offered suggestions. It is noteworthy that most of the time teachers agreed on the changes done to the prototype with little criticism. Most changes teachers suggested were in terms of the learning content retrieval system which was changed after a series of Re-Designs.

Figure 34. Teachers and developers during supervision meetings.

This process was highly iterative as suggested by Co-CreARGBL method and a stable prototype was reached by early march 2016. The prototype is described in section 5.2.

EVALUATION IN CLASSROOM

After a stable prototype was built, the team felt ready to test the game in a naturalistic environment. These were the activities conducted. The Figure 35 shows the timeline of this stage.

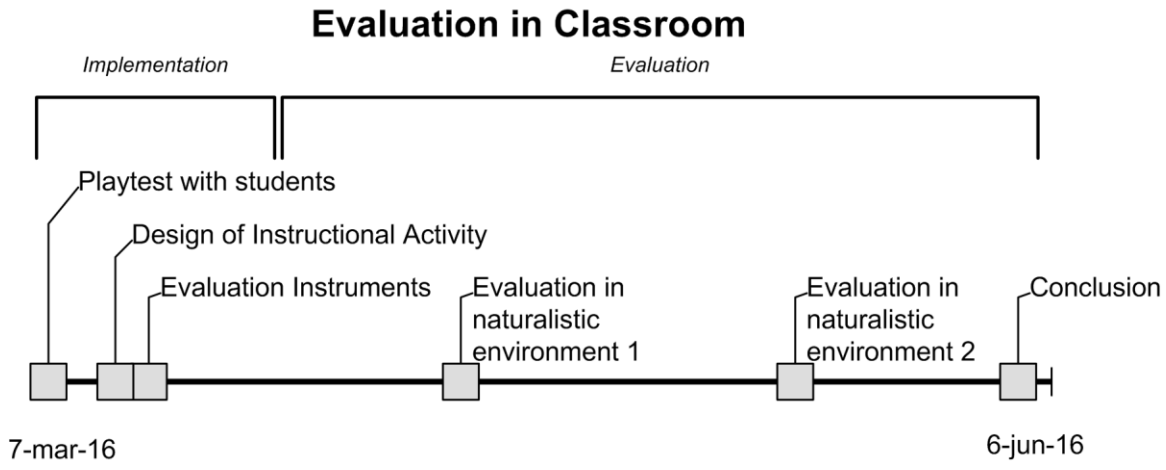


Figure 35. Timeline of Evaluation in Classroom Stage with Team A

Implementation Activity: Leaders and Teachers were able to find a set of schools able to test the game on. The implementation activity was brief, and during this time:

- Teachers designed an instructional activity including the game and a script for the class using it, following the ATMSG model (Carvalho et al., 2015) and defined the activities to be held during a test class.
- Teachers designed an evaluation instrument meant to be used as a regular instrument used during regular activities in the classroom. This was a set of questions meant to observe the knowledge of the students about the department.
- Developers installed the necessary software and the team arranged and adapted the necessary printed materials.
- A rehearsal of the class was done during a set of playtests with Students.

Evaluation Activity: The evaluation activity consisted mainly in two scenarios where the game was tested. These scenarios were naturalistic environments as proposed by the Design-Based Research Approach (Barab & Squire, 2004). These scenarios were natural because they comprised a set of 15 and 30 students respectively, who interacted in their natural classroom with their teachers and their regular companions; this was opposed to a laboratory setting. In these naturalistic scenarios the "messiness" of the learning context (Barab & Squire, 2004) was not controlled, and students were free to explore the game and follow the learning session. Figure 36 shows a photograph of this setting.

Figure 36. Students, Researchers and Teachers during the Evaluatoin Activty in a naturalistic environment

During this activity Researchers devised a protocol to be followed in order to test students and perform observations on them (on motivation and learning aspects) as shown in the next chapter. Also, the

protocols stated a series of guidelines for the guiding Teachers and other teachers who participated in the experience.

Also, Researchers devised a survey to gather observations and opinions on other teachers about the game. These teachers were called "Peer-Teachers" and they answered with their opinions about the quality of the game as a learning object. Conclusions on this survey are shown in chapter 6.

The Evaluation in Classroom stage allowed the team to perform re-design on the game, as proposed by Co-CreARGBL method, which says that after the third stage there is a possibility to return to the Iterative Design stage in order to perform changes.

5.2 DESCRIPTION OF THE PRODUCTS OF WORK WITH TEAM A: "UNA AVENTURA POR EL CAUCA"

In Team A, after Teachers conducted satisfactorily the Iterative Design Stage a game was completed in a stable version prototype. This game was an Educational Videogame with AR, as classified by the continuum shown in previous chapters, whose learning objective is to identify the richness (geographical, touristic, ecological, and historical) of the Cauca department. This game, called "*Una Aventura por el Cauca*" (*"An Adventure through Cauca"*), is displayed in a mobile device pointing towards a marker-referenced map (Figure 37-a).

The game's main mean of interaction is a set of AR markers printed with icons depicting the intended use. These markers are AR "paddles"(Hornecker & Dünser, 2009) which show relevant imagery regarding their use and that allow to interact with the virtual information on the AR game. For example, students can use the "chiva" marker (a "chiva" is a traditional Colombian bus) to move through the different municipalities and to get to know them, the chiva marker (a paddle) shows the face of the touristic guide (Figure 37-b). Other interactions include the "newspaper" and the "computer" markers which give information about the municipalities and other means of transportation, such as the plane and the boat on the municipalities where they are available (Figure 37-c).

In the game, the Students must act as a touristic guide whose mission is to lead the "invisible" alien visitors (who become visible through the mobile device) to their desired destinations according to their requirements (Figure 37-d). For this, students may familiarize with the characteristics of each municipality through an information system designed to give facts about the municipality (the learning content) and other game-related information (Figure 37-e).

When Teachers proposed the learning objective, they also proposed a set of themes that the game should deal with. In this case, they are: Generalities, Tourism, Festivities, Hydrology, Archaeology and Economy. These themes are present in the mechanics of the game and Teachers with Designers created a set of levels each of which dealt with a particular theme.

Along with the game, Teachers proposed an Instructional Activity to be used with the game which revolved around the themes and the learning objective. The Instructional Activity involved not only the game but an Info Sheet that was designed by the Teachers using the same educational content that was embedded into the game and that was deployed as a Web Site. The Info Sheet included the same educational content in the game to ensure *Information Equivalence* (Larkin & Simon, 1987) between the game and the written material. This was done because the Researcher used an instrument to compare the students' motivation using the game and the Info Sheet.

(a) Board and printed markers

(b) Interaction with the municipalities

(c) Detail of printed markers ("paddles")

(d) Alien characters

(e) Information System

Figure 37. Snapshots of the ARGBL game produced by Team A

During the Instructional Activity, Teachers first introduced the Students to the themes of the game performing a conversation about why it is important to recognize the richness of their region. The Instructional Activity was designed because the design model chosen by the team was the ATMSG model (Carvalho et al., 2015), and it proposes serious games (wherein games for learning can be found) as tools aimed to a learning objective in which three activities are involved: A gaming activity, a learning activity and an instructional activity. Since the game was considered the gaming and learning activity (playing and learning from the Informational System) an instructional activity was required to be designed. Teachers proposed a plan for an Instructional Activity involving a discussion about the department previous to the game, a reading of the notebook (made with the learning content adapted by teachers) followed by the playful activity with the ARGBL game and a de-briefing session after the playful activity.

Also, Teachers designed an evaluation instrument consisting on a set of open-ended questions meant to observe the knowledge gained by Students during the activity in the classroom.

5.3 DESCRIPTION OF TEAM B'S WORK: AN ARGBL EXPERIENCE ON PHILOSOPHY AND TRADITIONS

The roles fulfilled by Team B's Teachers are the same as in Team A. In this section the details about the work with Team B are described. In Team B, four teachers participated originally in the project. However, the main work was done by two of them. The other two teachers participated scarcely due to their inability to assist to design meetings because they belong to an indigenous community and transportation to the place were those were being held was, often, very difficult. The Table 13 shows information gathered about the two teachers who stayed the most in the project.

Table 13. Characteristics of the Teachers on Team B

Code	Subjects	Courses	Have you used…				
			Playful Activities	**Board Games**	**Digital Games**	**3D Objects**	**AR**
TB1	Philosophy and indigenous traditions	Elementary School	On several occasions	On a few occasions	On a few occasions	Never	Never
TB2	Mother Tongue and Natural Sciences	High School	On a few occasions	On several occasions	Never	Never	Never

Similar to Team A, Team B was comprised of Teachers who were not familiar with AR but used to use playful activities in the classroom, similar to those used by Team A (nursery rhymes, memory games and so on). In Team B, however, Teacher TB1 showed to be very fond of games and their use in the classroom, believing in their efficacy. She explained that she liked to use *Role Games, Imagination games, and Digital Interactive Reading Games* in the form of animated textbooks. Teachers in Team B belong to an indigenous school, thus, their roles as teachers in Philosophy and Mother Tongue differ somewhat to those of regular schools. In the school, philosophy refers to the traditions and values of the Nasa culture and Mother Tongue refers to the Nasa Yuwe language instead of Spanish as in other schools in Colombia.

Teachers agreed very early in the project on working on a learning objective that could mix the two subjects since they are tightly related.

As in team A, the team agreed on using *Google Groups, Google Drive,* and *Dropbox* as means of communication and sharing.

As for the professionals participating in Team B, their roles were defined from the beginning of the experience according to Co-CreARGBL method. Team B had the participation of two artists who helped in the graphic design and the creation of graphics assets. The roles were fulfilled as follows:

Table 14. Professionals in AR and GBL in Team B

Professional	Roles	Comments
PB1	*Leader, (Head) Designer, Researcher*	This participant refers to the main author
PB2	*Leader*	This participant acted as assistant and was the main contact with schools, teachers and students in the city
PB3	*Designer, Developer*	This participant acted as Programmer

PB4	*Designer, Developer*	This participant acted as Programmer
PB5	*Developer*	This participant acted as an Artist
PB6	*Developer*	This participant acted as an Artist

Figure 38 shows the timeline of the work with Team B.

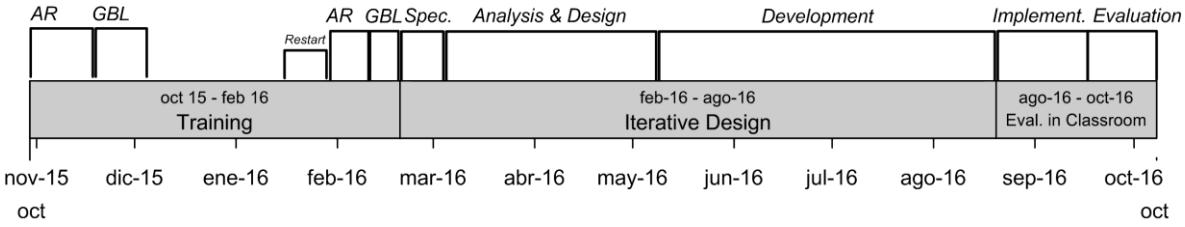


Figure 38. Timeline of Work with Team B

Notice some differences with Team A. Team B started the training process after Team A by late October 2015, because as has been said Teachers in Team B often had issues for attending the training sessions. Also, the training process spans until late February 2016. This is because teachers in Team B were not able to attend the design meetings in the last quarter of 2015, so they postponed the activities until 2016. In the beginning of 2016, the team had to restart activities. There was a repetition of the activities of the Training stage, just to remind teachers about the characteristics of AR and GBL and to give them a short introduction to ARGBL. Then, the Iterative process started as normal.

Next, each stage of the process is briefly commented.

TRAINING

The training process with Team B followed the same basic principles as with Team A. Teachers were also able to attend sessions on ARGBL games. The training stage with Team B benefitted from the experience with Team A, because at this point, many ideas and initial concepts were described by Team A, and thus, teachers in the Team B were able to observe them. Also, teachers in the Team B received feedback and recommendations by Teachers in the Team A.

The Figure 39 shows the timeline with specific milestones for the Training stage with Team B.

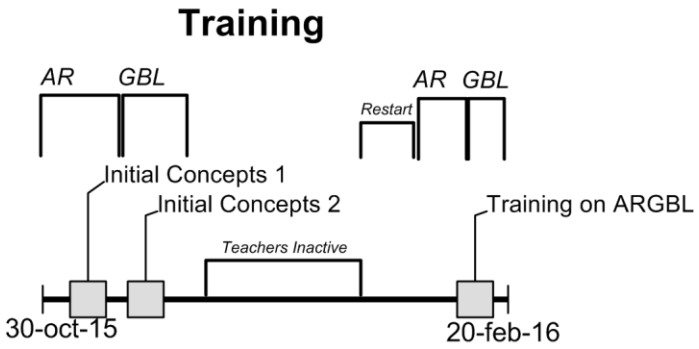


Figure 39. Timeline of the Training Stage

During the Training stage, Teachers were able to experiment with the same tools that Team A used. Also, teachers were able to observe the early versions of the digital prototypes made for Team A, this leads to think that Teachers in Team B had a clearer idea of the kind of results that the design and development Team could achieve.

Teachers in Team B proposed 2 Initial concepts of game during the Training stage, advancing the process to the surprise of the other members of the team. However, the ideas proposed by the Teachers were not used because they were too complex for the development team. Nonetheless, these ideas were proposed later during the Iterative Design stage, and served as the main base for the final product.

ITERATIVE DESIGN STAGE

During the Iterative stage, Teachers were able to share educational contents to the other participants of the team. Since the theme chosen by Team B were the traditions and values of the Nasa indigenous culture, most of the philosophical concepts explained by the Teachers were not known by the other members of the team. Thus, as a matter of fact, this stage was used as a learning stage for the members of the team who were not familiar with the topics. The Iterative Design stage started with the exploration of several ideas and designs. After Specification and Analysis, the process was smoother and the development had not many issues. The Figure 33 shows the timeline of this stage.

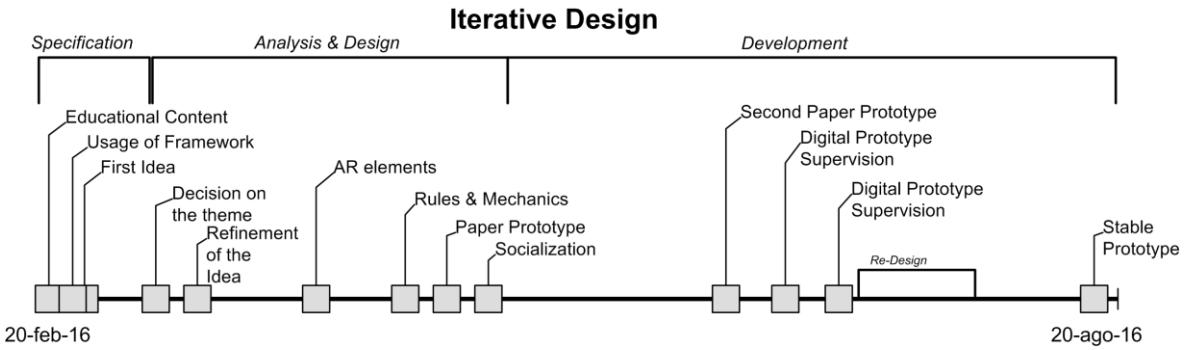


Figure 40. Timeline of Iterative Design Stage with Team B

The same structure of tasks and division of work used with Team A was used with Team B. The activities were conducted as follows:

Specification Activity: Early design meetings were used to explore the original ideas proposed by the teachers in the Initial concepts 1 and 2. The concepts dealt with several aspects of the indigenous culture and life. The aspects included social issues, the relationship with the outer world, the labor, the community and the family values.

The educational content was provided by the "cabildo" the political organization that manages the indigenous community to which the school belongs. The contents were in the form of videos, slides, textbooks and other media that is used at the interior of the community. These contents are used by the teachers when teaching these subjects. Teacher TB2 is a native speaker of the Nasa Yuwe language, thus, he was the main source of the content regarding this aspect of the game.

Analysis Activity: Since the educational content was varied and teachers wanted to include many ideas into the game, the initial game ideas were too convoluted for the team. To solve this, the team used the "Framework for proposing the ARGBL game idea" which is a part of Co-CreARGBL. Figure 41 shows a picture of a Teacher participating during the brainstorming session. The screen behind him shows one of the templates of the framework. Note how in the photo the Teachers have already passed through the phase of proposing ideas on post-its; they have arranged them logically according to the AR and GBL criteria in the framework and they are discussing them.

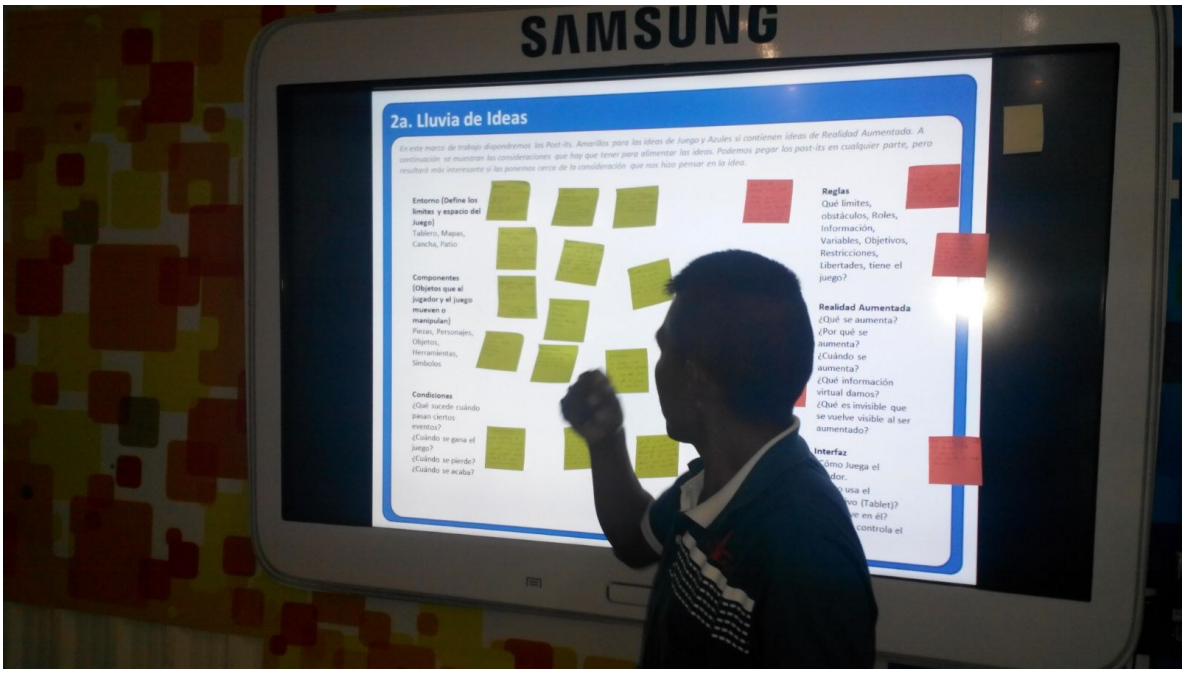


Figure 41. Teacher of the Team B using the Framework for creating the ARGBL idea

The *Analysis* Activity using the framework proposed by Co-CreARGBL allowed the team to define a narrower idea which included only the sub-theme of family values inside the Nasa culture. With this idea and process, the general rules of the game and the main mechanics were defined. The resulting idea was about a Board Game with AR, explained in the next section.

Design Activity: The team met every two weeks. The main goals of the meetings were, initially, to refine the elements of the general game idea. Thus, during this first part of the design stage, the team met to define elements such as:

- **The AR "augmentable" elements**: These were meant to identify elements of the day-today life in the community.
- **The goals of the game:** The goals were to fulfill the role of the Nasa man and woman. The goal is to marry two characters in the game.
- **The inclusion of educational content:** It was decided to include a sub-system in the game that allowed the player to query the meaning of each of the Nasa-related symbols and elements in the game. Also, the system allows hearing the pronunciation of the words in Spanish and in Nasa-Yuwe.

The process was similar to the one followed for Team A. The Team B used Google Drive to create a Game Design Document and define each element of the game. The main difference with Team A is that as this game belonged to an indigenous school, it was very important for the Teachers to socialize the project with the students, their parents and the "cabildo" authorities. Hence, the design team was invited to socialize the project with the community.

Development Activity: The development activity was conducted similarly to the one conducted in Team A. Nonetheless, given that this team had the participation of artists, illustrators and animators, the Teachers were able to express with them and the art was inspired in the traditional culture of the Nasas.

During this stage, Developers acting as artists defined a set of conceptual arts that would be included in the game. The Designers included these aspects into a second Paper Prototype that resembled the final board game. Programmers built the software as usual.

During this stage the Teachers participated in various ways. Some Teachers participated as design supervisors. TB1 was present each week checking on the board game design and the right inclusion of the educational content. TB2 and other supporting teachers helped by creating music, getting and adapting videos and creating the educational content in Spanish and Nasa Yuwe. TB2 and a Student participated as the voices of the game.

As in team A, this process was highly iterative as suggested by Co-CreARGBL method and a stable prototype was reached by august 2016. The prototype is described in section 5.4.

EVALUATION IN CLASSROOM

After a stable prototype was built, the team felt ready to test the game in a naturalistic environment. These were the activities conducted. The Figure 42 shows the timeline of this stage.

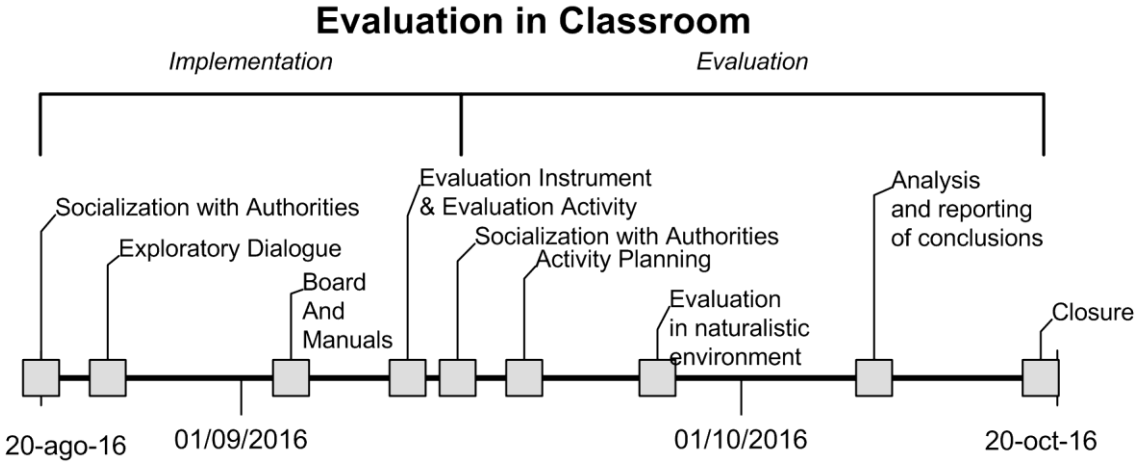


Figure 42. Timeline of Evaluation in Classroom Stage with Team B

Implementation Activity: During this activity the process was conducted as recommended by Co-CreARGBL. However, the Teachers demanded a socialization of the final prototype with the indigenous authorities as they wanted to check how it was finished.

After this, Teachers conducted an exploratory dialogue with the students who would participate in the evaluation of the test and their parents. This exploratory dialogue allowed teachers to perform a diagnostic evaluation on the Students by exploring how much did the Students know about the themes in the game. The exploratory dialogue was done under the “tulpa”, a traditional conversation setting around the fire which is used highly inside the indigenous community. The dialogue which was guided by one of the Teachers, explored the traditional values that are described inside the game.

Figure 43. The exploratory dialogue conducted by Teachers under the *"Tulpa"* (a traditional dialogue setting in the indigenous community)

The other members of the team printed and adjusted the boards and other necessary materials to conduct the evaluation. The Teachers proposed an evaluation instrument which was meant to be used along an Instructional Activity. The Teachers also planned to propose an evaluation activity after the game experience.

A third and final socialization was done with the authorities. This time, the team delivered the boards, materials, software and manuals during an official act to the "cabildo" managers.

Evaluation Activity: The evaluation activity was done in a naturalistic environment. This environment was the indigenous school where the Teachers participating in the project worked. The evaluation activity was conducted with 13 students with ages between 8 and 10 years old.

Similar to Team A, the evaluation activity included a diagnostic evaluation and a formative evaluation. However, those evaluations were not performed quantitatively as demanded by the Teachers. Their demand was based on the traditions on the school and the organic nature of the subject which is not evaluated with standard test.

Hence, the diagnostic evaluation consisted in a "diagnostic dialogue" with the students, which was used by Teachers to evaluate Student by Student under a qualitative approach. After the diagnostic dialogue the Students and the Teachers used the ARGBL game devised and performed the instructional activity with it. The students played in groups and they managed to finish the game. Most of the Students were able to finish the game by accomplishing the goals. Figure 44 is a photograph of the diagnostic dialogue, and Figure 45 and Figure 46 show the students during the learning activity.

Figure 44. Students and Teacher participating on the Diagnostic Dialogue

Figure 45. Students, Teachers and Researchers during the Evaluation Activity in a naturalistic setting

Figure 46. Detail of student interacting with the ARGBL game

After the activity with the game, the Teachers proposed the formative evaluation activity which consisted in asking the students to create a picture and a presentation using what they had learned during the game activity. Also, students filled a motivation instrument based on the IMI as with Team A.

After this process was ended the Researcher collected the data and structured the results which were used in the arguments of the validation shown in chapter 6.

Future activities with the game and the method are expected with teachers on the Team B as they remain very interested and supported by their community and the school.

5.4 DESCRIPTION OF THE PRODUCTS OF WORK WITH TEAM B: "CUETAYA: TIERRA DE COLORES"

The process conducted with Team B resulted in the creation of an ARGBL game called "Cuetaya: Tierra de Colores" (*Cuetaya: Land of Colors).* The game is a board game with AR as classified by the continuum proposed in chapter 5. The game is a Mobile Video-Displayed Marker-based AR game as classified by the classification shown in chapter 2. The game is displayed in a mobile Android tablet or smartphone. The game works by pointing the camera to a game board with a set of marker pieces which represent the elements of the game (Figure 47). The accompanying website shows links to videos and photos of the game in action (http://bcds.udg.edu/ARGBL/proyectos/cuetaya/).

Unlike the game in team A, Team B's main interaction tends to be with the physical elements (pieces and board) rather than with the GUI; this renders the ARGBL game more similar to a board game than to a videogame. The AR system implemented within the software application allows the game to work as a source of information that involves the educational content. It also allows the Students to query the Nasa Yuwe pronunciation of the elements in the game (Figure 48-a).

The game's goal it to marry the two characters: *Sek* (*Sun*) and *Çxayu'Çe (Happiness*) (Figure 48-b). The marriage has to happen before a lunar year ends, and they must accomplish the requisites of the Nasa community (which are the same as required by the Nasa tradition). In order to get this, the students have to work within the game in the traditional labors of the Nasa people: working the land, and knitting hats and "jigras" (a type of artisanal holding bag). Also, the characters have to work collaboratively to build their house under the traditional architecture. All of the elements and traditional concepts are explained within the game. While not working, the game pauses as to give the Teachers the opportunity to interact with the students and explain the underlying concepts.

Figure 47. Board of the ARGBL Game Created by Team B

Nasas work under a lunar calendar, which was used even before the Columbian era. This calendar known as *A'te Dxi'J* (*the path of the moon*) is printed in the game board and as an interactive version of the original calendar showing relevant information (Figure 48-c). The calendar is playable; it presents a woman that walking throughout its path (in the Nasa culture, the moon is represented as a woman) and passing through the stages of the moon. It also shows information on the different seasons of the year. Based on these stages and seasons, the game is affected positively or negatively according to the Nasas traditions. The mechanics used for this incidence on the game elements were defined by the Teachers.

The game also deals with social and economic aspects of the culture by introducing the traditional barter that was used in the community before the introduction of money. The game has a marketplace where items can be exchanged for corn and other materials such as wool, wood and other construction materials and *cabuya* (a plant used to extract knitting materials). Students have a special marker set that represents the storage of the elements which can be seen in 3D through the AR application (Figure 48-d).

At the end of the game, if the Students managed to accomplish all of the objectives, the game presents a video documentary on Nasa family values and the game concludes.

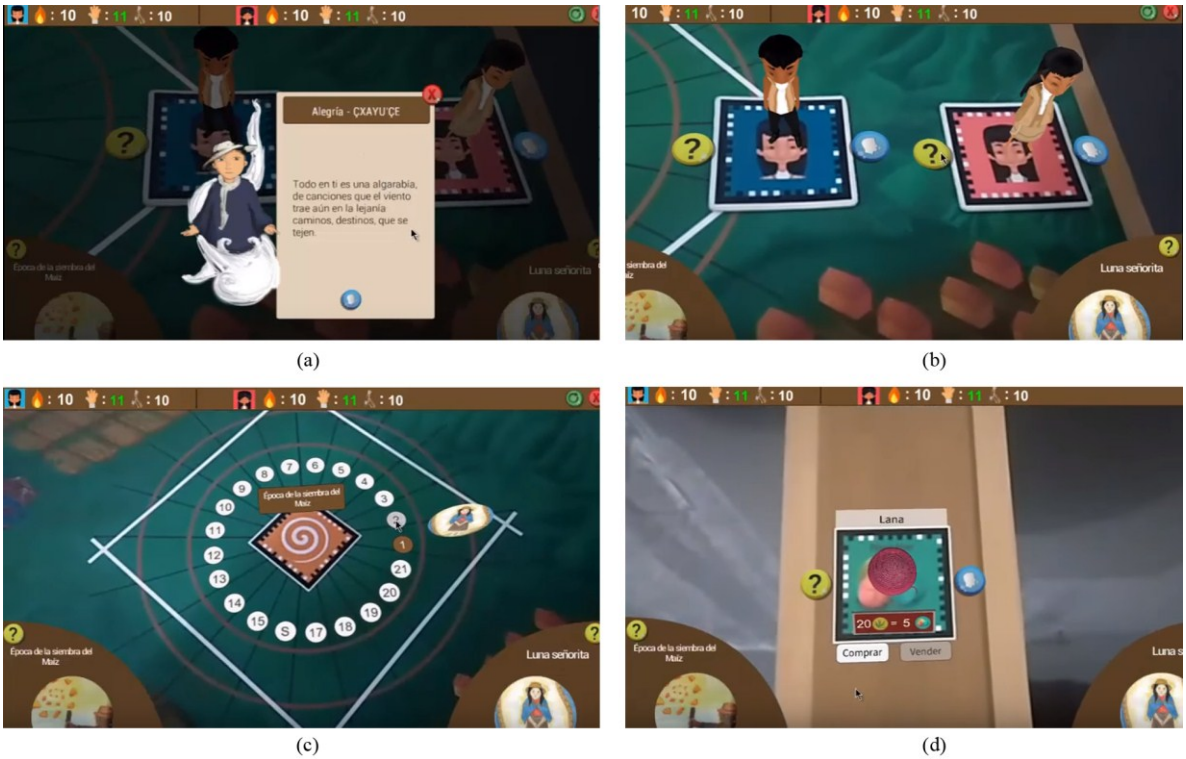


Figure 48. Snapshots of the ARGBL game produced by Team B

Other products of the process include the definition of the activity that was used during the class accompanying the ARGBL game i.e. the Instructional Activity, the evaluation instrument which was used to perform the assessment, and the definition of the evaluation activity that was performed after the session with the game. This process of evaluation was used during the validation of the method, which is explained in chapter 6.

5.5 CONCLUSIONS OF THE CHAPTER

In this chapter the application of the method to two case studies with real teachers and the corresponding ARGBL products has been shown. Also, in this chapter the process for designing and developing the game has been described making special emphasis on the work made by teachers and Designers following the Co-CreARGBL method. Moreover, a description of the work conducted in order to evaluate the products has been done.

With these two case studies, it is considered that the method has been correctly applied in order to perform the validation of the method and it also works as a demonstration of the use of the method meant to inform future projects.

In chapter 6, these case studies are taken as the base to perform observations on the process, the Teachers and the resulting product in order to validate the Co-CreARGBL method according to a set of defined conditions.

6 VALIDATION OF THE METHOD THROUGH THE CASE STUDIES

In this chapter the process of validation of Co-CreARGBL method, using the case studies described above, is shown. The case studies were meant to be used as a case of implementation of the method, and their participants, the products obtained, and the events that happened were used as a mean to validate the method as an effective way to guide the process of Co-Designing ARGBL games with Teachers.

In order to validate the method, the Validation Square (VS) framework (Pedersen et al., 2000; Seepersad et al., 2006) was used. The VS is a framework used to validate design methods that considers the validation of a method as the process of "… *building confidence in the usefulness [of the method] with respect to a purpose"* (Seepersad et al., 2006). The VS was selected because unlike other traditional process of validation (like mathematic, scientific and rigorous validation), VS considers validation in a holistic and semiformal way which, as its main authors and other adherents consider, is appropriate to validate design methods that involve aspects difficult to measure and more *subjective* considerations. To feed the validation process and thus, build confidence on the validity of Co-CreARGBL in the reader, it was decided to observe a set of attributes of the process and validate according to some defined criteria. The attributes were meant to include several perspectives that are important to the process, involving the Teachers who participated as designers, the resulting products, the students who participated in the evaluation process and other Teachers who participated as peer-reviewers of the products. The attributes considered are mentioned in the previous chapter and they are: Completion, Quality of the Product, Satisfaction and Comprehension by Teacher who participated as Designers.

An analysis was conducted on the whole process in order to observe these attributes. A mixed-methods approach was used to conduct the analysis on the attributes as shown by the case studies used.

It is noteworthy to mention the importance and effort placed on this validation process. The validation process reinforces the characteristics of the method as a strategy to leverage ARGBL experiences to the classroom. Hence, the process was done carefully during each step (stages, activities) of the process of design conducted in the two case studies. The process was conducted by the main researcher of this thesis, who in the case studies acted in the role of Researcher as suggested by the Co-CreARGBL method. Thus, conducting both, the research meant to validate the process and the research typical to each design process.

In this chapter, the VS framework is briefly explained and the actions performed in order to accomplish VS's conditions (also explained here) are shown. The actions involve the attributes observed and hence, they are explained and related accordingly. Later, the results of the observation are shown. This results include the observations and analysis of the data gathered during the execution of each of the case studies. Note that some of these analyses are qualitative and some are quantitative allowing observing the participants of the process and the resulting products from various perspectives.

6.1 STRUCTURE OF THE VALIDATION PROCESS

Authors of the VS adhere to a relativistic/holistic/social school of epistemology (Pedersen et al., 2000; Seepersad et al., 2006) arguing that for some design methods, the validation ought not to be a rigorous formal process of mathematical validation. Instead, they argue that for those methods the validation is more of a social process of building confidence on the usefulness of the method with respect to a purpose.

In this sense, usefulness of a design method is considered to be whether the method provides design solutions correctly (i.e. its effectiveness) and whether it provides design solutions with acceptable operational performance (i.e. its efficiency).

Authors of the VS propose that a design method is a process which uses a defined input (information and resources) to come out with an output (a design solution). This understanding of a design method is compatible with the definition of Co-CreARGBL as it stands as process whose input are the participants and the requirements or needs to build and ARGBL game and its output is an ARGBL game and an instructional activity for it to be used with.

The VS is summarized as a Square Diagram that crosses two axes: the theoretical-empirical axis and the structural-performance axis (depicted in Figure 49). Thus, the square considers four types of validities. For each of those validities the VS proposes a set of Acceptance Conditions (AC) that help to build confidence on the method. Here the validities and their ACs are briefly summarized:

- **Theoretical Structural Validity (TSV)**: Validity of the internal structure of the constructs of the method and their relationship to previously accepted constructs, known as "parent constructs".
    - ***AC (1) Accepting the constructs validity:*** The method is valid given that it is based on accepted constructs (theories, concepts, structures, strategies or approaches).
    - ***AC (2) Accepting internal consistency:*** *The method proposes an adequate flow of information.*
- **Empirical Structural validity (ESV):** Validity of the structures used when validating the method with an actual experience used as both: an illustrative example and a test case for the method.
    - ***AC (3) Accepting the example problem(s)*****:** The method is validated using a set of example problems that are adequate to be used with the method.
- **Empirical Performance Validity (EPV):** Validity of the method's performance when used with the example experiences.

- ***AC (4) Accepting usefulness of the method for the example problem(s):*** *The method shows to be useful when applied to the example problems.*
- ***AC (5) Accepting the usefulness is linked to the method:*** The useful results of the conducted process are related to the application of the method.

- **Theoretical Performance Validity (TPV):** Validity of the method's performance when used in other scenarios other than the ones in the examples used.
  - ***AC (6) Accepting usefulness of the method beyond examples:*** The method is useful and valid in general for problems adequate to its application.

It is important to have in mind that while for TSV, ESV and EPV documentation and arguments can be given in order to demonstrate its validity and thus attain acceptance, it is virtually impossible to demonstrate TPV as it refers to the general use of the method in the intended domain of application. For this, VS authors propose that TPV is only deduced by logically arguing on the premises of the previous validities. They call this a "Leap of Faith", because it requires believing in the validity of the method to be used in the future.

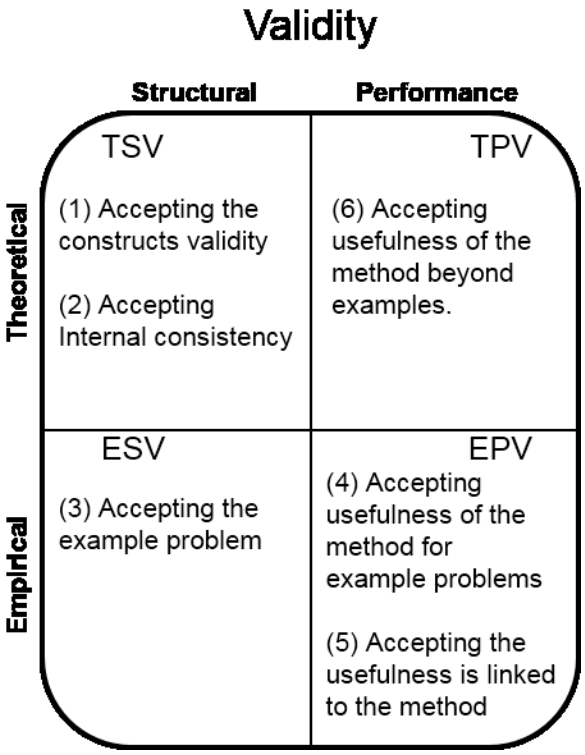


Figure 49. The Validation Square (Seepersad et al., 2006)

For each of the six ACs (indexed with parentheses in the figure) defined by the VS, a set of arguments are exposed in this chapter as for validating the Co-CreARGBL method. VS suggests some actions to follow in order to conduct the argumentation on each of the ACs. Consequentially, in this chapter the arguments given are accompanied by corresponding documentation and they follow the suggestions stated by the VS. Not that for the EPV, as it relates to the usefulness of the method in the case studies, the attributes abovementioned are included as part of the arguments and documentation.

Next, for each of the ACs, the arguments and their corresponding documentation for the validity of Co-CreARGBL are described. The next sections in this chapter explain them on detail.

- **TSV:** For the AC (1) *Accepting the Constructs Validity* an argument is given based on the benchmarking that was performed in order to construct Co-CreARGBL. Co-CreARGBL is a method whose structures rely on previously identified and accepted constructs (roles, procedures, structures), and thus those are shown here marked as "parent constructs". For the AC (2) *Accepting Internal Consistency* a flow diagram is shown depicting the flow of information of the method arguing for its internal consistency.
- **ESV:** For the AC (3) *Accepting the Example Problem* the two case studies are checked against the critical characteristics of the domain of application of Co-CreARGBL arguing that they are similar enough as to be accepted as valid example problems.
- **EPV:** The AC (4) *Accepting the usefulness of the method for example problems* is the one dealing with the usefulness of the method on the case studies. To build confidence on this validity the attributes of *Quality of the Product* and *Satisfaction of the Teachers* are considered and documented. The following are the data used and analyzed for these attributes:
    - **Quality of the Product:** This attribute is seen from both, the perspective of peer-teachers and the perspective of students. A survey for assessing the quality of a game for learning was conducted and filled by 14 teachers for the Team A and by 18 Teachers for Team B. An analysis on the motivation enhanced by the games using the Intrinsic Motivation Inventory (IMI) (Ryan, 2006) on the students was done. The learning gains were assessed using the evaluation instruments designed by the corresponding teachers on both teams. Both assessments on motivation and learning gains were quantitatively analyzed and are shown here. Both perspectives (students and peer-teachers) add up to the Quality of the Product which in turn adds to accepting the usefulness of the method.
    - **Satisfaction of the Teachers:** An interview was conducted on each of the Teachers participating in both teams at the end of the process. The interviews were qualitatively analyzed using *Thematic Analysis* (Braun & Clarke, 2006) and the resulting themes are shown here as documentations for arguing in favor of the satisfaction of the Teachers which in turn add up to the usefulness of the method.

  As for AC (5), *Accepting the usefulness is linked to the method,* two attributes are documented and considered: The attribute of Completion and the attribute of Comprehension by the Teachers:
    - **Completion:** With this attribute it is argued that the teachers and the design team completed the tasks suggested by Co-CreARGBL and thus, adding up to build confidence on the usefulness being linked to the use of the method.
    - **Comprehension by the Teachers:** A set of three semi-structured interviews per teacher were conducted on the Teachers on both Teams. At the start of the process, during the process and after it was finished. The interviews asked teachers about their understanding of the process. A qualitative analysis of the interviews was done using *Thematic Analysis* (Braun & Clarke, 2006). The identified themes are shown arguing for the comprehension of the method by the teachers and thus adding up to build confidence on the usefulness of the method being linked to the use of the method
- **TPV:** A deductive argument is given based on the previous documented and argued validities to accomplish AC (6) *Acceptance of the usefulness of the method beyond examples*.

The Table 15 sums up the relationship between the ACs and their validities and arguments.

Table 15. Acceptance Conditions and their corresponding arguments

Validity	Acceptance Conditions	Arguments
TSV	AC (1) Accepting the constructs validity	Review of Co-CreARGBL's parent constructs.
	AC (2) Accepting Internal consistency	Review of Co-CreARGBL's flow of information.
ESV	AC (3) Accepting the example problem	Review of Accomplishment of critical characteristics of the method on the case studies
EPV	AC (4) Accepting usefulness of the	Review of Quality of the Product and Satisfaction

Validity	Acceptance Conditions	Arguments
	method for example problems	of the Teachers
	AC (5) Accepting the usefulness is linked to the method	Review of Completion of the Co-CreARGBL's activities and Comprehension by the Teachers.
TPV	AC (6) Accepting usefulness of the method beyond examples.	Deductive argument

In the next section the results of the validation for each of the acceptance conditions are developed.

6.2 RESULTS OF THE VALIDATION

In this section, arguments for the validity of the method are given following the structure of the validation process mentioned in the previous section. This section serves the purpose of showing the arguments and the documentation gathered in order to gain acceptance and validate the method using the case studies as example problems for the VS.

This section is divided in the four validities. For each one, arguments are presented following the suggestions of the VS for each of the ACs.

6.2.1 ARGUMENTS FOR THEORETICAL STRUCTURAL VALIDITY (TSV)

Structural validity refers to the consistency of the constructs proposed in the design method. This consistency is considered externally as internally. To build confidence on the external consistency of the method, in this section, reflection and arguments are presented on the relationships of the method with previously accepted and published constructs in which Co-CreARGBL is based on. Also, to build confidence on the internal consistency of the constructs of the method a flow diagram is presented in Figure 50 showing the informational flow that should occur during the application of Co-CreARGBL, and thus arguing of its adequacy. Next, arguments for the two ACs in TSV are presented.

This section presents arguments for both of the ACs on the TSV.

AC(1) ACCEPTING THE CONSTRUCTS' VALIDITY

Co-CreARGBL is a method based on the paradigm and methodology of Co-Design for Learning, as it has been explained in previous chapters. And thus, its roots go deep into the philosophy and considerations of working hand on hand collaboratively with the practitioners of learning and teaching: the Teachers. Co-CreARGBL is an instance, in terms of structure, procedure and roles of widely used and accepted traditions of participatory design like *Rapid Prototyping* and *Co-Creation* (Ramaswamy & Ozcan, 2014) because it proposes the creation of prototypes collaboratively with the teachers. Co-CreARGBL follows the paradigm of *Team-Based Design* and *Learner-Centered Design* because it requires a team of creative people (Teachers and Designers) to fulfill its activities. Also, Co-CreARGBL promotes that the designs follow the needs of the students. Moreover, the process followed when applying Co-CreARGBL can be considered *Design-Based Research* because it involves Researchers, Designers and Teachers working to leverage designs and experiences to be used and analyzed in the classroom (Barab & Squire, 2004).

Co-CreARGBL proposes a set of roles that fulfill the expertise needed for designing a serious game as defined by the Six Facets of Serious Game Design Model (Marne et al., 2012). The Six-Facets Model defines a framework that was used as parent construct for Co-CreARGBL method. It defines a set of facets that, as authors argue, form part of the Serious Game and thus are to be considered during the design process. The authors of the Six Facets Model divide the Facet into the ones requiring *Pedagogical Expertise* and the ones requiring *Game Design Expertise*. In the Co-CreARGBL method, the roles of Teachers and Designers are assigned with the corresponding Pedagogical and/or Game Design expertise.

One of the main procedure structures in which Co-CreARGBL relies is the ADDIE process structure for creating learning objects (Branch, 2010). The ADDIE process is widely accepted as a way to leverage instructional design. A more specific instance of the ADDIE process, called the SADDIE process (Rugelj, 2015; Zapušek & Rugelj, 2014) was used as a parent construct to propose the structure of activities in Co-CreARGBL. The ADDIE process is a valid process as it is accepted by the community of scholars and people involved in instructional design. While the SADDIE process is relatively new, it conserves the structure of ADDIE and adds an additional activity – the S stands for Specifications – in order to allow the identification of learning objectives of the instructional design. The SADDIE process justifies and adds to the validity of the sequence *Specification, Analysis, Design, Development, Implementation, and Evaluation* that Co-CreARGBL proposes.

But there is also a bigger structure in Co-CreARGBL, the stages structures. While the *Iterative Design* and the *Evaluation in Classroom* stages are simply a division of the final activities in the SADDIE process. The first stage *Training* was created because AR and Games for Learning are not known generally by teachers, and because Co-CreARGBL is meant to be a long process of learning. Thus, as proposed by Penuel and Roschelle (2007), the Co-Design process is started by a bootstrapping event. The training process is an instance of such a bootstrapping event, and a very effective one, because most teachers will be prone to a training process and then, after recognizing the aspects of the creative process, they will be able to judge whether they want to participate or not.

The Iterative Design stage is iterative because it is the recommended procedure to create AR and Games for Learning as it is recommended by previous methods and structures. For example Santos et al. propose an iterative process for co-designing AR experiences (Santos et al., 2013). Azuma in the paper that defines AR emphasized the need to create applications with an iterative design process (Azuma et al., 2001). Also the principles provided by Cuendet et al. (2013) propose that they should be instantiated through an iterative design process involving teachers and students. Iterative Design is a construct that is also used in Game Design methods and paradigms. The MDA framework proposes an iterative process of refinement of the mechanics in a game (Hunicke et al., 2004) and other processes like the "Playcentric Approach" stress the need of an iterative design process (Fullerton, 2008a). The Six Facets of Serious Game Design (Marne et al., 2012) is aimed to be used in an iterative design context. All of the mentioned constructs are previously accepted and they were used as parent constructs for the Co-CreARGBL method.

The Co-CreARGBL methods suggests for the *Specification* and *Analysis* activities to document *Learning Objectives* and the main characteristics of the game to be designed. During these stages a brainstorming process is conducted using the "*Framework for Proposing the ARGBL game idea*" as shown in previous chapters. This framework is a part of the Co-CreARGBL method and it is designed considering accepted parent constructs. The framework is based on the MDA framework (Hunicke et al., 2004) as it asks Designers and Teachers to define the main *Aesthetics, Dynamics and Mechanics* of the game. It also, allows Teachers and Designers to consider the context of the Students, and other aspects of the game such as the main components, and the environment. These concepts are taken from the structure defined by the Theory of Game Elements (Järvinen, 2008) which is used as a parent construct. The framework for defining the game idea also takes concepts from the structure of games defined by Jesse Schell (Schell, 2008) including the Augmented Reality elements of the game as defined by previous conceptual frameworks regarding the design of AR experiences (Cheng & Tsai, 2012; Santos, Chen, et al., 2014; Yuen et al., 2011).

The Designers are advised, during the *Design* activity, to "scaffold" Teachers. This term is used in congruence with the use it has been given in other Co-Design endeavors (Carroll et al., 2000; Cober et al., 2015; Sanders & Stappers, 2008). And thus, it is an important part of the method. The *Design* activity proposed the creation of prototypes and the formalizing of the design decisions into Game Design Documents. Prototypes and Game Design Documents are widely accepted as constructs needed in the process of Game Design (Fullerton, 2008b; Kultima & Paavilainen, 2007). Teachers and Designers in the Design activity are also encouraged to identify "augmentable" objects and to consider existing

frameworks of AR for the classroom design, recommending principles of design such as the principles of *Integration, Empowerment, Awareness*, *Flexibility* and *Minimalism* (Cuendet et al., 2013)

During the *Implementation* activity, Teachers are encouraged to create an Instructional Activity to accompany the game. The Instructional Activity is understood as a parent construct as defined by the Activity Theory and as proposed by more recent Models for Serious Game Design (Carvalho et al., 2015).

Co-CreARGBL suggest to perform the *Evaluation* activity as a mean to evaluate no only the usability and other aspects of the software and its AR characteristics, but as a mean to evaluate the worthiness of the game as a learning tool. In this sense, techniques are suggested based on previous experiences with AR and Games for Learning, and based on the paradigm of Design-Based Research (The Design-Based Research Collective, 2003) which aims to perform the evaluation in naturalistic environments (Barab & Squire, 2004).

Finally, while the constructs recommended by Co-CreARGBL for each of the "consideration" on each activity are not specifically "parent constructs", because they are not a root for the method. They certainly add up to the acceptance on the constructs of the method, because Co-CreARGBL lets the participants on the process to choose the models, frameworks, and other constructs for each activity as they suit the team's needs. Nevertheless, Co-CreARGBL gives various recommendations, on what constructs to choose, especially those regarded as important staples and scholarly recognized.

To sum up, the table shows the relationship between the constructs of Co-CreARGBL, their corresponding parent construct and how they give support to the method.

Table 16. Summary of the method's constructs and the relationship to their parent constructs

Co-CreARGBL's construct	**Parent constructs**	**Support**
Paradigm and General Philosophy of the method	• *Co-Creation* (Ramaswamy & Ozcan, 2014) • *Co-Design for Learning* (Hunicke et al., 2004; Järvinen, 2008; Schell, 2008) • *Team-Based Design, Learner Centered Design, Design-Based Research* (Roschelle & Penuel, 2006)	General form of the method, its applications and intended uses.
Roles	• Six-facet Model (Marne et al., 2012)	Base for the definition of the roles and their jobs.
Activities	• ADDIE and SADDIE processes (Branch, 2010; Rugelj, 2015)	Sequence of activities and their goals.
Training stage	• "Bootstrapping event" (Roschelle & Penuel, 2006)	Event to initiate the process.
Iterative Design stage	• Iterative process (Azuma et al., 2001; Cuendet et al., 2013; Fullerton, 2008b; Marne et al., 2012; Santos et al., 2013)	The need and structure of the iterative process.
Framework for proposing the ARGBL game idea	• MDA and Game elements and components (Hunicke et al., 2004; Järvinen, 2008; Schell, 2008) • AR elements (Cheng & Tsai, 2012; Santos, Chen, et al., 2014; Yuen et al., 2011).	Important elements of the ARGBL game to be defined by Teachers and Designers.
Scaffolding	• Previous use of the term (Carroll et al., 2000; Cober et al., 2015; Sanders & Stappers, 2008)	The importance of supporting the design of the Teachers
Instructional Activities	• ATMSG (Carvalho et al., 2015)	Structure and use of the game during an Instructional Activity.

AC (2) ACCEPTING INTERNAL CONSISTENCY

Internal Consistency refers to the way the constructs are assembled in the method. Accepting the consistency means accepting that for each step in the method, there is the adequate input and output (Seepersad et al., 2006, p. 17). The Figure 50 shows the flow diagram depicting the flow of information as proposed by Co-CreARGBL.

In the flow diagram, it is shown how since the beginning, each step feeds the subsequent steps. It shows, at the beginning, a set of tasks performed before the process in which the teachers participating on the training stage will be selected and Leaders will get in contact with schools.

Then, after the Training stage has been ended, it is expected to have teachers trained in the Design Models (DM) and the Principles (Ps) to be used during the design. These principles, as has been noted during the description of the method, guide the process of creating Games and AR applications. When the Iterative Process starts, the Teachers (T) and the Designers (D) that will participate in the process are selected. Then the SADDIE process starts.

The activities during the SADDIE process have the necessary input and the adequate output for the subsequent activities. For example, the *Specification* activity should define the Learning Objectives (LObjs), the Educational Content (Eco) and (optionally) the Evaluation Criteria (ECr) in a Specification Document (SD). Note how those elements are being used afterwards in the process. LObjs are used during the *Design* activity to define the Game Objectives (GO) and these are used to define the *Augmentable Objects (AO)* that will form part of the ARGBL game. The *Analysis* analyses the elements defined in the SD and creates an ARGBL game idea (perhaps using the framework that Co-CreARGBL proposes) and produced an Analysis Document (AD). Then, the Design process defines the rules, mechanics and augmentable objects, interactions and information, based on an iterative process that, when necessary, returns to the activities of *Specification* and *Analysis.*

The elements defined during the *Design* activity then feed the *Development* activity which in turn outputs a prototype to be used during the Evaluation in Classroom stage. The activities on the last stage utilize the prototype and define a Learning Activity and Materials based on the ECo and the ARGBL game. During these activities an optional Evaluation Instrument can be designed based on the ECr. From there, there can be a reiteration if needed, looping back to the Iterative Design stage.

It can be considered that Co-CreARGBL shows Internal Consistency, because the flow of information during the process allows the actors of the process to have adequate information during each of the steps Also, the method shows the output of information for each steps, helping the actors of the process to focus on the definition of the elements of the ARGBL game that are needed during each stage.

As it has been shown in this section, the method shows validity of the constructs because the constructs it is based on are accepted and its process, structure and roles are based on literature findings. Also, the information flow shows internal consistency. Therefore, since both Acceptance Conditions pertaining to the Theoretical Structure validity have been shown here, it can be considered that method fulfill the requirements to accept its validity in this sense.

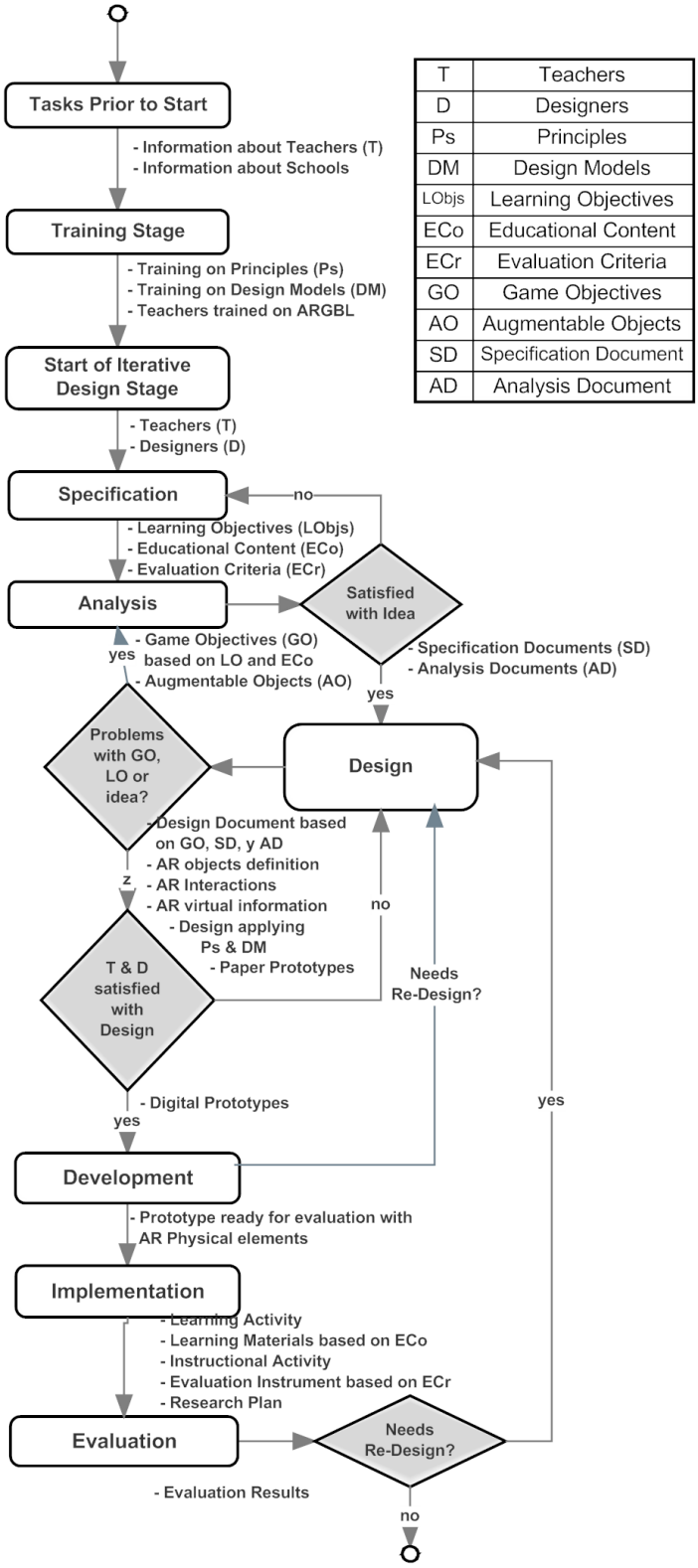


Figure 50. Diagram of information flow in Co-CreARGBL

6.2.2 ARGUMENTS FOR EMPIRICAL STRUCTURAL VALIDITY (ESV)

While TSV refers to the theoretical validity of the method, this is, independent of the domain of an actual application of the method; the ESV refers to the validity of the structure when applied to a set of examples (used for illustrating the application of the method and to validate it), this is, depending on the domain of the examples. This involves building confidence on the appropriateness of the examples used, and that requires the examples to be similar to the problems for which the design method is generally accepted or intended.

AC (3) ACCEPTING THE EXAMPLE PROBLEMS

In order to accept the Example Problems the characteristics of the case studies used for validation (Team A and Team B) are compared against the critical characteristics of the problems to which Co-CreARGBL method is intended. The critical characteristics of the example problems are taken from the intended uses of the method explained in section 4.2.1.

Table 17. Critical Characteristics of Co-CreARGBL compared against the Characteristics of the example case studies.

Domain of the method	**Team A**	**Team B**
Heterogeneous groups		
Teachers	✓	✓
Designers	✓	✓
Developers	✓	✓
Leaders	✓	✓
Researchers	✓	✓
Students	✓	✓
Different Types of Image-Based AR Games		
Board game with AR		✓
Videogame with AR	✓	
Teachers with different experiences on ARGBL		
Teachers with experience on AR		
Teachers without experience on AR	✓	✓
Teachers with experience on Playful Activities		✓
Teachers without experience on Playful Activities	✓	✓
Different Subjects		
One Subject	✓	
Multi-Subjects		✓
Characteristic of the Process		
Long Process	✓	✓
Craftsmanship Process	✓	✓
Dialogue Process	✓	✓
Types of AR Tracking		
Image-Recognition	✓	
Marker-Recognition	✓	✓
Markerless		
Simple AR	✓	✓
Designing complex games (non "flashcards" games)	✓	✓
Testing in Naturalistic Environments	✓	✓

Table 17 shows the various characteristics for which the method is intended and what of those characteristics are accomplished by each of the cases in the case studies. The "Heterogeneous Groups"

shows how the two case studies involved different creative actors as suggested by Co-CreARGBL. Most of the roles were used in both teams; in Team B, Students also participated creating some of the contents for the game. Both types of games with AR as defined by the continuum defined in chapter 4 were used in the case studies as shown in the characteristic "Different types of Image-Based AR Games".

The characteristic "Teachers with different experiences in ARGBL" shows how the method is intended for Teachers with various backgrounds. However, in the two case studies only Teachers with little to no experience participated. Naturally, it is to be expected that better results would come out would the case studies involve teachers with experience on ARGBL.

The method can be applied independent on the quantity of subjects. Team A worked mainly with one subject (Social Sciences) while Team B worked with two subjects (Philosophy and Mother Tongue).

As has been stated previously, the method is not intended to be used as a one-shot rapid method of designing ARGBL experiences. Instead it is to be used in long process of craftsmanship and dialogue between the creative actors. Given that as shown in the chapter 5, both teams worked during months in the projects and there was a constant communication between the Designers and the Teachers, the case studies can be considered to accomplish to these characteristics. Moreover, field notes on the design meetings documents that the design process was an organic process that took the form of a craftsmanship process, rather than a process mediated by automatic means. Thus, it can be considered that it accomplishes these characteristics too.

Regarding the types of AR Tracking, the two case studies involved Marker-Recognition and Image-Recognition according to the taxonomy shown in chapter 2. None of the cases involved Markerless AR. However, the differences are subtle, and thus it does not affect the similarity of the cases to the intended problems.

The method is intended for Simple AR as the term used in (New Media Consortium, 2010). Co-CreARGBL is meant to be used by small teams perhaps lacking funding and with simple devices as available in schools. Thus, in both Teams, only simple devices and techniques were considered.

Since Co-CreARGBL is meant to be used in a process of craftsmanship, the outputted games should be a model of the learning content (Gee, 2009) and because of this, complexity in the game should arise because in learning games this is important (Prensky, 2005b). Also, this is opposed to the "flashcards" games as mentioned by (Klopfer et al., 2009).

Finally, as it was shown in chapter 5, both of the experiences were tested in naturalistic environments as suggested by Co-CreARGBL and Design-Based Research (Barab & Squire, 2004).

As has been shown, the example cases used to illustrate and validate the model are similar to the ones the method is intended for by looking at the critical characteristics of the domain of application of the method. This should add up to the confidence on the examples problems used to validate the method which is the one AC in the ESV.

6.2.3 ARGUMENTS FOR EMPIRICAL PERFORMANCE VALIDITY (EPV)

The EPV is the one regarding the utility of the method when used in a set of illustrative examples (the case studies already discussed and accepted as valid). Thus, special attention was paid to this type of validity and its ACs (4 and 5). This validity contains the so called "Attributes" of the validation as discussed at the beginning of this chapter.

In this section, the ACs (4) and (5) are discussed presenting the attributes of the process as resulting from the process of data-gathering, observation, and analysis performed during the execution of the case studies as a mean to build confidence on its validity.

AC (4) ACCEPTING THE USEFULNESS OF THE METHOD FOR THE EXAMPLE PROBLEMS

For this AC, two of the attributes of the process were considered since they give information on the usefulness of the method as stated by its requirements. These attributes actively and purposefully include the vision of the Teachers, because the method considers them view as the final judges of the usefulness of the results and products of the process. The two attributes included in this AC are *Quality of the Product* and *Satisfaction of the Teachers*.

Attribute of Quality of the Product

The attribute of *Quality of the Product* is on of the most critical attribute regarding usefulness of the method, because it accounts for the most important results of the process which is the game and the experience involving the game in the classroom.

The *Quality of the Product attribute* involves two perspectives: The Quality in regard of two important benefits for the students (*Motivation* and *Learning Gains*) and *Quality from the Perspective of Peer-Teachers* seeing the product as a Learning Object.

For both teams, the *Motivation* was assessed using the IMI (Ryan, 2006). The IMI is a validated scale used to determine self-reports on motivation during the use of some sort of Learning Material. The scale presents a set of sub-scales depending on the objectives of the research and each sub-scale presents a set of questions answered using a Likert-Scale of seven points. The chosen sub-scales used for this study included Interest/Enjoyment (seven questions) Effort/importance (five questions) and Value/Utility (seven questions).

According to suggestions from (Mellor & Moore, 2014; Reynolds-Keefer, Johnson, & Carolina, 2011) the Likert scale was reduced to include only 5 possible answers to the questions, the questions were simplified and a smile-o-meter (a set of faces depicting how in accordance is the children with the question) was used. Also, the questions were adapted to be simpler and they were translated to Spanish. The instrument can be found in the Appendix E. The motivation assessment was done under the context of the Evaluation in Classroom stage during the evaluation in the naturalistic environments.

For Team A, it was done under the naturalistic environment 1 with 15 students aged between 8 and 10 years old (*M = 9.07, SD = 0.75*). 77% of the students are boys and 23% are girls.

For Team B, it was done under the naturalistic environment 1 with 9 students aged between 9 and 11 years old (*M = 10.00, SD = 0.86*). 55% of the students are boys and 45% are girls.

In both teams, Teachers and Researchers were able to perform a comparative study against a traditional learning material that teachers would use in this class. Teachers proposed an Info Sheet including the same educational content (text, images and data) included in the ARGBL game, but in the form of a searchable website. Thus, the IMI included, for each question, an answer for the Info Sheet and an answer for the ARGBL game.

The class was planned in such a way that the students first, interacted with the Info Sheet making use of tablet devices and then interacted with the ARGBL game. At the end of the class, students were asked to fulfill the IMI scale, reporting on their opinion on what was more motivating to them, comparing the Info Sheet and the ARGBL game.

The analysis of the motivation report using the IMI then was done by assigning a score to each of the Likert scale items (1 to 5 points). The scores were averaged for each sub-scale and a comparison

between the results for the Info Sheet and the ARGBL game was done. The Figure 51 shows a graph showing the final results.

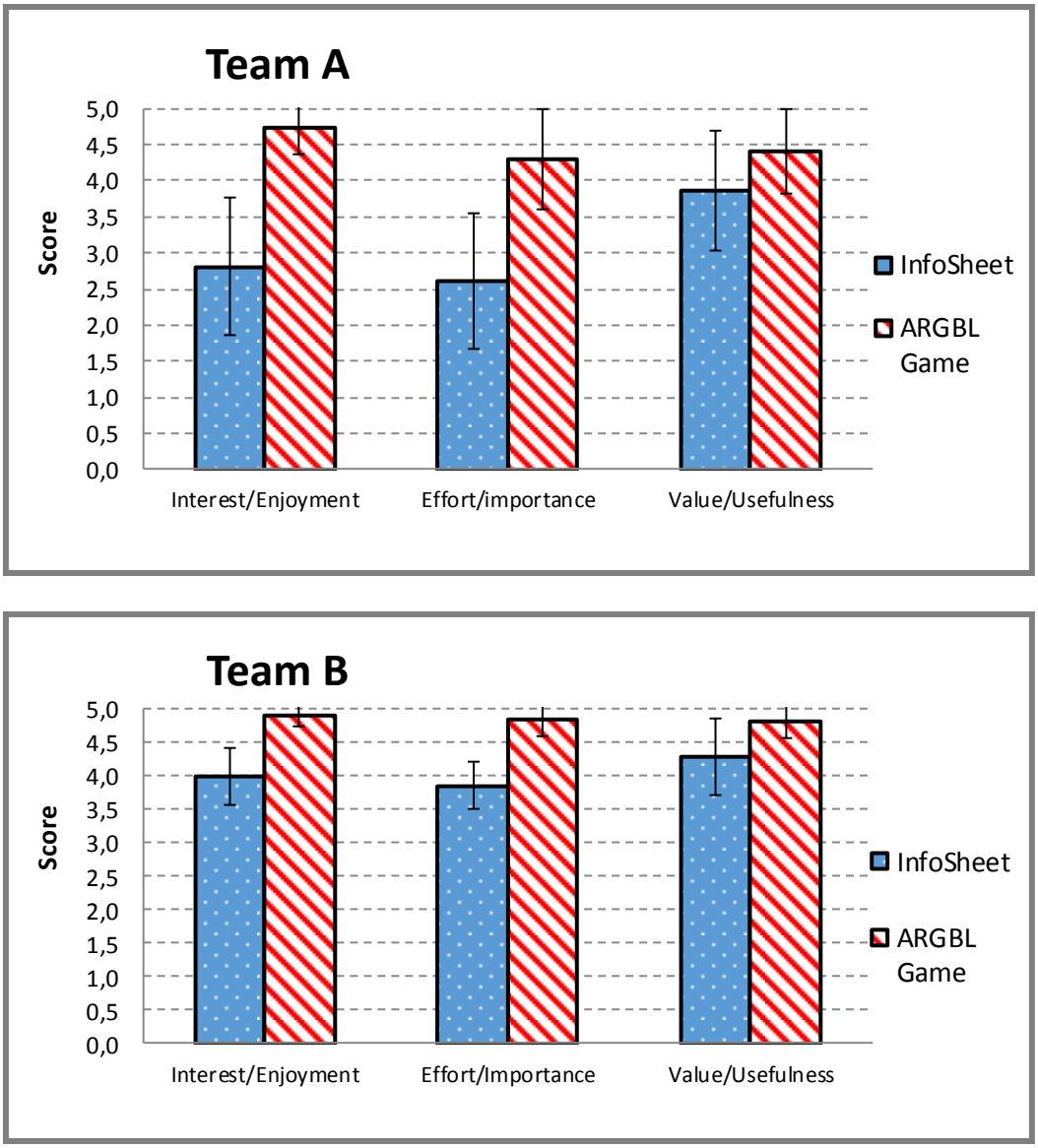


Figure 51. Results on the motivation assessment of both Teams's games against the Info Sheets using the IMI

A t-test performed on each pair of assessments resulted in a significant difference favoring the ARGBL Game over the Info Sheet (*p-value < 0.05* for both teams), which suggests that judging by these data, students feel more motivated with the ARGBL designed by their teachers than with the Info Sheet. The motivation data analyzed suggests that the product has quality in terms of the motivation of the children, from their point of view, which is useful as it is an important part of the product and to add up to the validity of the method used to produce it. It is important to recognize that this is the first time the students were presented with the game, and novelty factor can represent an important role in this assessment

In regard of *Learning Gains* in Team A, the process of observation and analysis of the data was agreed with the Teachers and the Researcher. The Teachers designed an Evaluation Instrument based on the themes planned for the game (described in the previous chapter) and the Evaluation Criteria defined during the *Specification* Activity. The Evaluation Instrument consisted on a set of open questions that dealt on the different regional and geographical aspects of the department of Cauca and that were related to the levels and educational content on the game. A plan to conduct the assessment on the students using the Evaluation Instrument was made. The plan consisted on asking the students the set of questions before the interaction with the game (a phase dubbed "Diagnostic Evaluation" by the Teachers) and after the game (dubbed "Formative Evaluation").

The Diagnostic Evaluation was performed one day ahead of the class in which the students would make use of the game. And the Formative Evaluation was planned to be done one day after. Both assessments were videotaped by the teachers. The assessment was oral as it allowed the students to express better that in written form. Students were free to answer in any way. 32 students participated in both Evaluations.

Then, the planned class was conducted including the Learning Activity that was planned by the Teachers during the Implementation Activity of Co-CreARGBL. After this process, the Teachers gathered and observed all of the videotapes. For each student, teachers used a scoring sheet to score their answers, using a rubric designed along the Evaluation Instrument (see Appendix F). The rubric gave a score of 1 to 10 on the answers of the students. Also, the scoring sheet allowed the teachers to answer some questions regarding the answer of the students, and whether they considered the students were sure on the answers and whether they find the particular student had a learning gain. From the 32 original participants 3 were not considered as due to special needs they were not able to answer the formative evaluation and 4 did not attend that day. Thus, the data for 25 students was analyzed. The Figure 52 shows the scores of the students during the Diagnostic and the Formative Evaluation for each of the themes defined in the Evaluation Instrument.

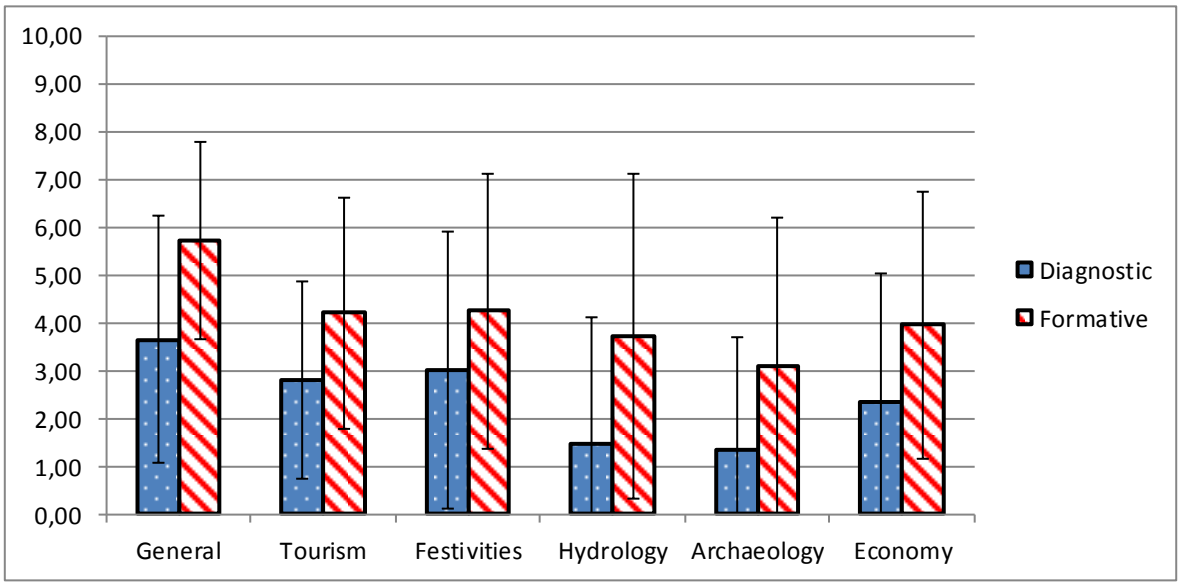


Figure 52. Scores of the Students in the Team A: Evaluation of Learning Gains

A Wilcoxon matched pairs signed ranks test was conducted on the scores data and it showed that a there is a significant increase in the scores ($N = 25$, $T = 25$, $p\text{-value} < 0.05$). As it is seen in the figure the media for the scores after the interaction with the ARGBL game increased for each of the themes. Nonetheless, while there is an increase in general, the scores are still very low, especially for the rightmost themes in the figure. This makes sense because, the rightmost themes were the themes the

games deals with in the latest levels and not every student was able to reach them on the time allotted for the session. Also, while an increase is seen in the scores, it is important to have in mind that this was only after one application of the game and the experience with the ARGBL, thus, and the subject is very complex and it is not expected to be covered after one session only. Longer studies on the interaction of the children with the game and the use of it in the classroom shall give more information on its effectiveness. However, the data shown here gives an account if the usefulness of the product and its quality as a Learning Object.

In regard of *Learning Gains* in Team B, Teachers planned a diagnostic dialogue to be conducted before the learning activity using the ARGBL game (see Appendix F). During the diagnostic dialogue, two researchers were present documenting it and taking field notes. A diagnostic text was generated based on the documentation (dubbed "Diagnostic Evaluation") for each of the students with the help of the Teachers to assess the students' previous knowledge of the themes planned for the learning session.

After the diagnostic dialogue, a gaming and learning activity was conducted in the classroom as was described in chapter 5. One day after the diagnostic dialogue and the learning activity, Teachers conducted an evaluation activity consisting on children drawing a picture of what they had learned during the interaction with the ARGBL game. In this subject in the indigenous school there is not a quantitative grading, because it is not customary to assess their knowledge of their traditions on such a way. Instead, after the evaluation activity the Teacher reported an evaluation text (dubbed "Formative Evaluation") on each of the students and a "Final Observations" text.

All the evaluation texts were analyzed by two independent researchers who agreed in a set of labels that were used to code each of the evaluation texts. Coders agreed to use the codes as defined in Table 18. The agreed formula to be used for each student was as follows:

<Category>:<Specification>:<Theme>

The category part of the code was used to define the aspect that was being observed in the students' answers or in the evaluative texts. The specification part of the code was used to concretize the aspect evaluated and the Theme was a free word that described what the evaluation was about. The themes included the themes in the educational content that were included in the game and others that the teachers manifest in the evaluation texts such as: *Nasa Calendar, Nature, Nasa Being, Moon, Crops, Harvests and son on*. For example, if one evaluator found that a student had some previous knowledge by recognizing the characteristics of the Nasa Calendar then the coding would be like this:

Previous Knowledge:Recognizes:Nasa Calendar.

Table 18. Codes used during the assessment of learning outcomes for Team B's Evaluation

Diagnostic Evaluation		
Category	**Specification**	**Description**
Previous Knowledge	Recognizes	The student recognizes the theme
	Gives Importance to	The student recognizes the theme as having importance
	Associates	The student associates the theme as a concept
	Considers themselves as a	The student considers themselves as the theme (this code only applies to the discussion about the Nasa beings)
Difficulty/Lack	Does not Recognize	The student does not recognize the theme
	Des not Give Importance to	The student does not recognize the theme as having importance
	Does not Associate	The student does not associate the theme as a concept
	Does not Consider themselves as a	The students does not consider themselves as the theme (this code only applies to the discussion about the Nasa beings)
Formative Evaluation		
Category	**Specification**	**Description**
Learning	This category has the same specifications as "Previous Knowledge" in the diagnostic evaluation	

Difficulty/Lack	This category has the same specifications as "Lack" in the diagnostic evaluation	
Final Observations		
Category	**Specification**	**Description**
Positive Outcome	The "Final Observations" assessment had no Specifications defined.	The teacher manifests general positive outcomes regarding the theme
Negative Outcome		The teacher manifests general negative outcomes regarding the theme
Inconclusive		

The evaluation was conducted by the coders to try and find the learning gains of students according to the judgment by the Teacher. The percentage agreement of the two researchers who coded the evaluation text was 68.57%. A final coding based on the codes of the two coders was agreed mediating by dialogue looking for a consensus. Table 19 shows the final consensus. In the table, codes with frequencies equal or greater than 3 are shown for each category.

Table 19. Coding consensus for the assessment of Team B's students' learning outcomes

Diagnostic Evaluation	
Category	**Codes and Frequency**
Previous Knowledge	Associates: Nature and Family (15) Considers themselves: Nasa Being (15) Recognizes: Nature items (14) Recognizes: Nasa Yuwe (7) Recognizes: Nasa Rituals (4) Recognizes: Uma and Tay (3)
Difficulty/Lack	Does not Recognize: Nasa Calendar (15) Does not Recognize: Moon Phases (14) Does not Recognize: Nasa Rituals (8)
Formative Evaluation	
Learning	Gives Importance to: Nature (7) Gives Importance to: Construction of the House (3) Gives Importance to: Family Values (3)
Difficulty/Lack	-
Final Observations	
Positive Outcome	Nasa Rituals (7) Nasa Calendar (6) Chumbes (3) Nasa Yuwe (3) Maize Crops (3) Traditional Barter (3)
Negative Outcome	-
Inconclusive	-

Further details on the coding can be found in the tabulation stored in the accompanying website.

An analysis of the results shows some highlights:

- Many students had prior knowledge regarding the Nasa Being and the Nature. These are students that are in constant contact with the nature being in a rural school and the relevance that the nature has to the community. This was relevant in the answers students gave during the diagnostic dialogue; most of them, felt very eager to answer and reveal their knowledge of nature.

- While some students revealed having some prior knowledge regarding the Nasa's traditions such as some rituals and the Nasa Yuwe language, most of them answered shallowly. This was one of the main concerns of the teacher who think that these traditions must be taught more deeply.
- Most students revealed a lack of knowledge on the themes of Nasa Calendar, the Moon Phases and the Rituals related to them. This was an important theme that the teacher wanted to be transmitted to students using the activity.
- Nonetheless, the formative evaluation texts do not reveal that students had learned about these themes. Perhaps, the Teacher does not recognize advancement by the students in these themes, or students did not reveal the themes during the evaluation activity.
- However, other themes were shown to be learned that were not present during the diagnostic evaluation such as giving importance to Nature, the construction of the house and the Family values.
- While not present in the Formative Evaluation (the drawing made by students), the teacher recognizes that generally students do recognize some basic concepts of the Nasa Calendar, the Nasa Rituals and the *Chumbes*.

As a final conclusion, judging by the coding of the evaluation texts, students seem to have acquired basic knowledge on the themes purported by the teachers. Nonetheless, in the main difficulties that students present (such as Nasa Calendar and the Moons) the evaluation was inconclusive as students did not show these themes during the drawing activity. Perhaps, the use of the ARGBL experience may result in clearer results would the themes were addressed directly by the teacher and not as part of a broader class.

On the bright side, the activity had a positive impact on the students by helping them to recognize the basic aspects of the Nasa's traditions and Family values. Future applications of the ARGBL experience and deeper studies are needed to conclude on the game and its experience's final impact.

As for the Attribute of **Quality of the Product** from the **Perspective of Peer-Teachers**, a survey to evaluate the Quality of the ARGBL as a Learning Object was used. The survey used was based on a Rubric for Evaluating Digital Educational Games (Stewart, 2015) that considers a set of considerations regarding pedagogical issues and Learner aspects. The survey used can be found in the accompanying website. The survey is based on Game-Based Learning principles and each question asks about a learning attribute of the Game. Each question is answered with a score of 1 to 4, where 1 means the game does not fulfill the requirements for quality in a particular attribute and 4 means that it fulfills all of the characteristics of quality.

For the Team A, 14 teachers completed the survey and for Team B 18 Teachers from indigenous schools completed the survey. Those teachers were either during the evaluation with the students or tested the game themselves. For example, some Peer-Teachers used the game in particular sessions apart from the classes with the Students while others were able to observe the evaluation process were the Teachers-Designers and the Students used the game in the naturalistic environments. The Peer-Teachers who participated were considered as being peers because they had similar occupations and experience to those who designed the game.

For Team A the age of the Peer-Teachers is ranged between 32 to 60 years old ($M = 47.2, SD = 8.1$) and they reported having from 3 to 38 years of experience teaching ($M= 17.2, SD= 9.9$). From the Peer-Teachers from Team A, 10 (71%) attended elementary school, 2 (14%) attended Middle School and 2 (14%) attended all of the educational levels. For Team B Teachers ages ranged from 24 to 63 years old ($M = 35.5, SD = 9.5$) and they reported having from 3 to 38 years of experience teaching ($M= 8.3, SD= 10.2$). From the Peer-Teachers from Team B, 8 (44%) attended elementary school, 3 (17%) attended Middle School, 2 (11%) attended all of the educational levels, the remaining 6 Teachers did not mark the corresponding field in the survey.

Results of the survey for Team A are shown in the Figure 53.

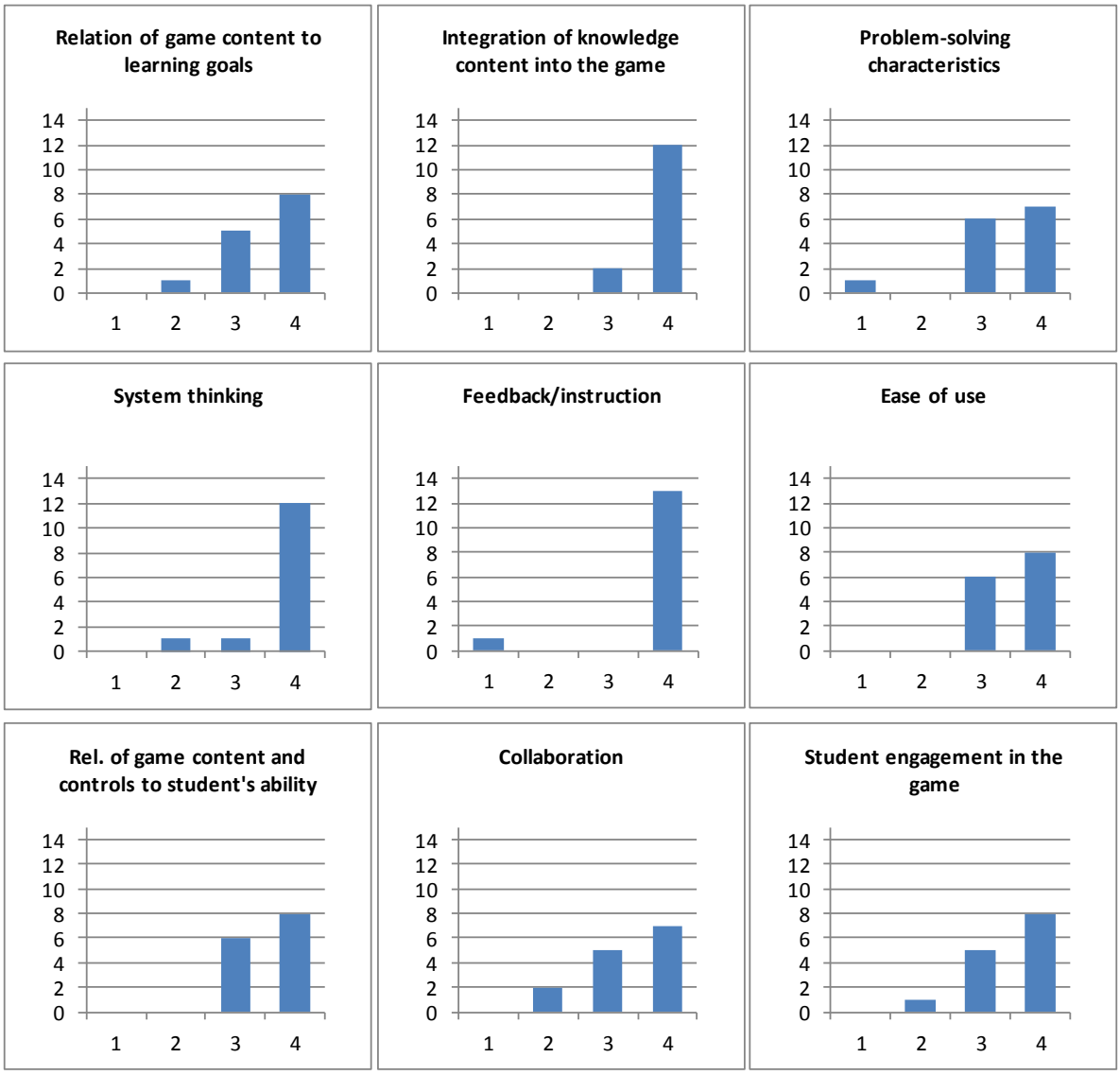


Figure 53. Results for the Survey on the Quality of Team A's Game completed by Peer-Teachers.

Most of the Peer-Teachers' answers to the survey are qualified as a score of 4. And as the survey asked for an explanation on their scoring it is possible to know the teacher's views. Some explanations are:

> *"There is a clear educational theme and the supporting concepts are identified during the game course in a playful and fun way. This constitutes an ideal complement to obtain meaningful learning based on the knowledge acquired previously in the classroom" (Score 4 in "Relation of Game Content to Learning Goals")*

> *"The challenges in the game keep the interest on it and the students improve their concentration, the problem-solving skills and the perseverance skill" (Score 4 in "Problem-Solving Characteristics")*

> *"Its functions are not that complicated and it uses an understandable vocabulary on its contents and its instructions" (Score 4 in "Ease of Use")*

"Children in Higher Grades are able to receive even more information" (Score 3 in "Relationship of Game Content and Controls to Student Ability")

While most of the scores were 4 and 3, some teachers scored some answers with a 2 or 1. The scores 1 or 2 in the rubric applied to those cases where the respondent think that the game does not accomplish the criteria at all (score 1) or the game accomplishes in some low level (score 2). Some of the concerns of the teachers are:

"The presentation of the information about the Educational Content should be more attractive" (Score 1 in "Student Engagement in the Game")

"I observed it only applied for Social Sciences; maybe it should apply to other subjects" (Score 2 in System Thinking)

Similar results were obtained from the survey applied to Peer-Teachers in Team B. Results are shown in Figure 54.

Among the explanation for the higher scorings (3 and 4) we can find:

I think this is a good pedagogical tool and a method to promote and improve the cultural knowledge in students (Score 4 in "Relation of Game Content to Learning Goals")

The amount of information given [in the game] might not be acquired by the student in the short time of the activity… (Score 3 in "Relation of Game Content to Learning Goals")

The game allows students to concentrate and employ strategies to achieve the learning objectives. (Score 4 in "Problem Solving")

The game adds [educational] information, but perhaps somebody who is not aware of the themes may not comprehend it easily. (Score 3 in "Integration of Knowledge Content into the Game")

There are some texts and information panels that show too much written information, given the dynamics of the game, this information may be omitted, so they will leave gaps in the knowledge of players. (Score 3 in "Feedback/Instruction")

While few in quantity some Peer-Teachers did answer with lower scores (1 and 2); however, Most scorings on the lower scores were not explained by the teachers (leaving the survey's space in blank) so it is difficult to assert and analyze their reasons to answer in such a way. Generally speaking some Teachers took issue with these aspects:

- Some incorrect aspects in the learning content (e.g. misspelled Nasa Yuwe words) that ought to be corrected.
- The need for a time to learn how to handle the controls on the digital game.
- The fact that the game may be used in a collaborative session, but that most of the interface is taught got a single player.

Finally, some Peer-Teachers did not mark or explain their answers (as shown in the figure by the answers NM (Not marked) or NA (Not Answer), arguing that for some questions they did not have the appropriate knowledge to judge the game, mainly because they do not belong to the Nasa indigenous community.

The fact that most of the answers are 4 (the rubric's greater score) as shown in the figures, suggests that the Peer-Teachers consider that, according to the rubric used, the games in Teams A and B accomplish their objectives and their characteristics are good as a Games for Learning.

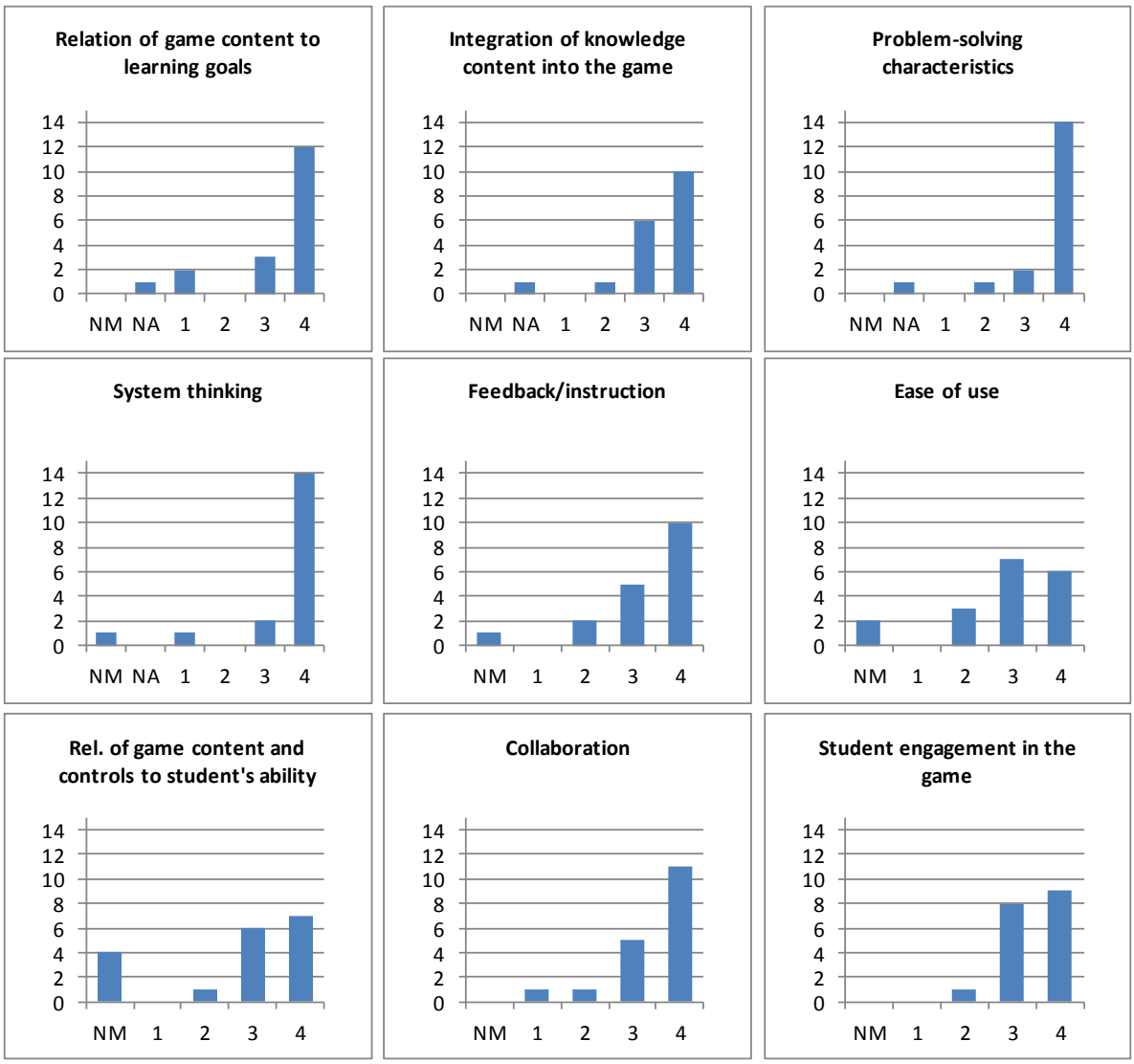


Figure 54. Results for the Survey on the Quality of Team B's Game completed by Peer-Teachers

Attribute of Satisfaction of the Teachers

The **Satisfaction of the Teachers** attribute was evaluated qualitatively using an interview at the end of the process. The interviews were semi-structured and they were done with each teacher individually. A Thematic Analysis of the interviews was conducted and here the main themes, regarding the satisfaction of the teachers with the process are briefly described. The original interviews and the recordings in audio and the comments and themes identified can be found in the Atlas.TI project stored in the accompanying website

While satisfaction was an underlying theme in all the interviews, the last interview was the one mostly interested in it. During this interview, there were particular questions about the satisfaction of the teachers with the process. The questions may be viewed in Appendix G.

The themes identified after the Thematic Analysis are discusses here. The first theme is "Reasons for Teacher's Satisfaction with the Process". In general, teachers declare to be very satisfied with the process and reasons include mainly satisfaction with the resulting product and its usefulness for their

work. The second theme is "Reasons for Teachers dissatisfaction with the Process". Some teachers mentioned during the interview some aspects that added up to a sense of dissatisfaction. While the aspects are relatively minor, they are discussed here. The last theme is "Future expectation of the Teachers". The teachers manifest that they would participate again in a similar process and that they would share its results with other fellow teachers.

Reasons for Teacher's Satisfaction with the Process

The most observed reason for teacher's satisfaction observed during the answers of the interview is the resulting product, especially the teachers felt most satisfied when they were able to view the early digital prototypes that clarified the whole potential of the technology and the development team. Some of the comments from Teachers are:

TA2: *It started to look more dynamic… more… concrete… when we saw the first 'sketch'*
I: *the Prototypes?*
TA2: *Yeah, the Prototypes*

TA3: *When you see the prototype is that you realize: 'oh ok, with everything that has been done is that the game materialized'*

TB2: *When we saw the prototype, we realized that we were doing one thing, and you were doing another, but, of course, based on our contributions*

This shows the importance of having periodical prototypes that teachers supervise, as the peak of teachers satisfaction comes when they see the product.

Some teachers do think that there was plenty of time to finish the process and thus they were satisfied.

I: *Do you think there was plenty of time to conclude the process satisfactorily?*
TA4: *Yes, and you can clearly see the results*

Teachers were asked to explain whether and why they feel satisfied with the process. Some of the answers include:

TA4: *I score it [the process] as a 10, because the results are optimal, because information contributed has been taken into account, because you can see a very… real … a very real structure and that truly shows benefits in our work as teachers.*

TB1: *I do like the final result [of the process]. It is attractive. At the beginning you start thinking 'where is this going to end' bout it ended up in something very good. At the end you see how what you have written has been embedded into something that will be useful in the classroom.*

Teachers also felt satisfied with the process, as they see usefulness in the process because it is a collaborative process.

I: *Do you think the collaborative process is useful, for your school?*
TA4: *Yes, there is no doubt. It is very useful, because we, as teachers would not have the means that the programmers do have, and vice versa, programmers find value in our pedagogical and didactical experience.*

TA2: *[One of the positive aspects of the process was]… learning to work collaboratively, which is something I had never done.*

TB1: *[One of the positive aspects of the process was]… for one, the collaborative work.*

TA1: *[One of the positive aspects of the process was]… that it was a collaborative work and there were contribution from everyone in the project.*

Teachers manifested during the interviews that they felt satisfied, when asked how they would score their satisfaction with the process, answers were between 8, 9 and 10. Their satisfaction relies mostly on the satisfaction with the product and the uses they can give it in the classroom.

Reasons for Teachers Dissatisfaction with the Process

During the interviews, some teachers had the opportunity to manifest whether and why they felt dissatisfied in any way with the process. Some teachers manifested concerns with the process taken. For example, the main concern identified is that teachers feel they did not dedicate enough time to the process. Some "guilt" can be identified from their answers.

I: *Do you feel the time allotted to the process was an obstacle for the success of it?*
TA1: *Yes, definitely. Because there are other responsibilities I have, and this is something that requires some time. Generally, when I compromise to something, and I haven't been able to fully compromise with this and that makes me feel bad.*
I: *Why do you think is that so?*
TA1: *Because of other activities, sometimes I am not able to attend to the meetings […]*

A3: *Often, the time we have must be dedicated to prepare classes, or maybe attend to personal affairs, so, yes it is an obstacle for sure.*

This is consistent with the "tensions" mentioned by previous studies on Co-Design (Carroll et al., 2000; Cober et al., 2015). In this case, while teachers do accomplish the assigned tasks, some of them feel the "guilt", especially when they compare themselves to other teachers that, on their opinion, contributed the most.

I: *How do you think was your performance on the project*
TA1: *Not Excellent […] Perhaps, regular or good. Because of the time, sometimes I wasn't able to attend the meeting. I always asked TA4, about the meetings. She was more active.*

Other reasons for dissatisfaction came from a sense of not identifying with the process at the beginning. One teacher manifested that he was looking to be in a long training process, and he was expecting more workshops and other learning activities. However, he also manifested that when the roles of the process were cleared, then he thought to participate anyways. The same teacher manifested that at some point, he felt that what added to materialization was more the "design" (perhaps referring to "development") of the engineers participating on the project.

Future expectations of the Teachers

While some teachers do see and declare some negative aspects of the process, most of their comments are positive aspects. At the end of the satisfaction interview, all of the teachers agreed on saying that they would participate again and that, as the results are satisfying they would share it with other teachers.

Nonetheless, while some teachers do feel appropriated of the final product and would share it:

TA4: *I appropriated the product because I consider I contributed with my time, and I accomplished with the assigned tasks and meetings at the maximum.*

TB1: *I feel I own the product. I think this is a tool that should be distributed; schools should use it to improve learning.*

Another teacher felt she just barely appropriated the product and another teacher said he did not appropriate the product. Teachers argues that, again, the first cause of this is that they did not allotted the right amount of time, and while they feel satisfied with the product they feel "guilty" that they did not participate more, which in turn, would have led them to feel more close to the game.

Here, reasons for satisfaction and dissatisfaction have been presented in such a way that positive and negative aspects of the process can be seen from the perspective of the teachers participating as designers. Although there are aspects that render the process as non-perfect, it is considered that the teachers felt satisfied in general, especially due to the results of the process in the form of the products, and the fact that the process was collaborative.

With this, the arguments for the usefulness of the products end. Arguments for the usefulness of the method have been shown, from different perspectives.

AC (5) ACCEPTING THE USEFULNESS IS LINKED TO THE METHOD

In this section, it is considered that the usefulness described and argued above is linked to the use of the method. To work towards the acceptance condition two attributes of the process are considered. The attribute of **Completion** which accounts for the completion of the tasks proposed by Co-CreARGBL and thus, how related was the project conducted with the guidelines of the method, and the attribute of **Comprehension by the Teachers** which accounts for how the teachers understood the process they were a part of, and thus, linking the actions of the teachers to the suggestions of the method.

Attribute of Completion

For the attribute of **Completion,** the Table 20 shows a summary of the tasks developed that were assigned according to the suggestions of Co-CreARGBL. The tasks are divided by Roles and they are checked whether they were conducted or not in each team. In the accompanying website the table can be found extended, stating the evidences for the completion of each tasks, the date in which it was completed and other comments.

Table 20. Completion of tasks in the Case Studies

Activity: Prior Tasks		**Team**	
Role	**Task**	**A**	**B**
T			
L	Contact Schools	X	X
	Organize Teachers Data	X	X
	Start Bootstrapping event	X	X
Ds			
Dv			
R	Plan Research over Teachers and Students	X	X
	Gather information about Teachers' experience	X	X
Stage: Training			
Activity: AR			
Role	**Task**	**A**	**B**
T	Attend to learning session	X	X
	Compliment data (Regarding Teachers knowledge of AR)	X	X
	Use and Explore AR applications	X	X
	Use and Explore AR Applications for Learning	X	X
	Use and Explore ARGBL applications	X	X
L	Conduct Learning Session on AR	X	X

	Show examples of AR and AR applied to learning	X	X
	Show Advantages & Uses	X	X
	Describe AR design Frameworks and Models	X	X
	Conduct examples of models and/or Frameworks for AR for Learning Design	X	X
	Show AR for Learning Principles	X	X
	Conduct Learning Session on ARGBL	X	X
	Show examples of ARGBL	X	X
Ds	Help Leaders acting as Instructors	-	-
Dv	Help Leaders acting as Instructors	-	-
R	Help Leaders acting as Instructors	-	-
	Gather information about teacher's experience with AR	X	X
Activity: GBL			
Role	**Task**	**A**	**B**
T	Attend to learning session	X	X
	Compliment data (Regarding teachers knowledge of GBL)	X	X
	Use and Explore GBL Applications for Learning	X	X
	Use and Explore ARGBL applications	X	X
L	Conduct Learning Session	X	X
	Show examples of Games for Learning	X	X
	Show Advantages & Uses	X	X
	Describe GBL design Frameworks and Models	X	X
	Conduct examples of models and/or Frameworks for GBL design	X	-
	Show GBL Principles	X	X
	Conduct Learning Session on ARGBL	X	-
	Show examples of ARGBL	X	X
Ds	Help Leaders acting as Instructors	-	-
Dv	Help Leaders acting as Instructors	-	-
R	Help Leaders acting as Instructors	-	-
	Gather information about teacher's experience with GBL or Games in the classroom	X	X
Stage: Iterative Design			
Activity: Specification			
Role	**Task**	**A**	**B**
T	Propose Learning Objective	X	X
	Propose Educational Content to be used in the game	X	X
	Propose Learning activities that can be used in the game	-	X
	Propose Evaluation Criteria to be used with the experience	X	-
	Propose Evaluation instruments to be used with the experience	X	-
L	Check and approve for Product Quality	X	X
Ds	Scaffold Teachers' Specification document	X	X
Dv	Participate in Design Sessions	X	X
	Offer visions to the design regarding technical capabilities	X	X
	Offer visions to the design regarding effort and budget	X	X
R	Collect Documents to conduct analysis	X	X
Activity: Analysis			
Role	**Task**	**A**	**B**
T	Perform Brainstorming session	X	X
	Propose Game Objectives based on Learning Objectives	X	X
	Propose Game Feelings and Aesthetics	X	X
	Propose Target Player's characteristics and context	-	X
	Propose Main Game Dynamics	-	X
	Propose Main Game Mechanics	-	X
	Select Educational Content	X	X
	Adequate educational content	-	X
	Define Game Winning, Losing and Ending Conditions	X	X
L	Check and approve for Product Quality	X	X
Ds	Scaffold Teachers' Analysis Document	X	X
Dv	Participate in Design Sessions	X	X
	Offer visions to the design regarding technical capabilities	X	X

	Offer visions to the design regarding effort and budget	X	X
R	Collect Documents to conduct analysis	X	X
Activity: Design			
Role	**Task**	**A**	**B**
T	Build Paper Prototype	X	X
	Write Game Design Documents	X	X
	Define Markers and markers behaviors	X	X
	Define Tracking behavior	X	X
	Define Main ARGBL Interaction	X	X
	Define Augmentable objects	X	X
	Fin-tune details after Evaluation in classroom	X	X
	Conduct Re-iterations	X	X
	Design Interface	X	X
L	Check and approve for Product Quality	X	X
Ds	Write Design Document	X	X
	Evaluate Teachers' Paper Prototype	X	X
	Guide Teachers	X	X
	Show inspiring and relevant examples to teachers	X	X
	Scaffold Teachers' Main Design	X	X
	Build Paper Prototype	X	X
	Define Markers and markers behaviors	X	X
	Define Tracking behavior	X	X
	Define Main ARGBL Interaction	X	X
	Fine-tune details after Evaluation in classroom	X	X
	Conduct Re-iterations	X	X
	Design Interface	X	X
	Guide Application of the design model	X	X
Dv	Participate in Design Sessions	X	X
	Offer visions to the design regarding technical capabilities	X	X
	Offer visions to the design regarding effort and budget	X	X
R	Collect Documents to conduct analysis	X	X
Activity: Development			
Role	**Task**	**A**	**B**
T	Build Physical elements	X	-
	Illustrate characters and elements	-	-
	Adjust educational content	X	X
	Include Educational content in developed game	X	X
	Fin-tune details after Evaluation in classroom	X	-
	Conduct Re-iterations	X	-
L	Check and approve for Product Quality	X	X
Ds	Supervise Development according to Design	X	X
Dv	Develop the ARGBL game according to Design	X	X
R			
Stage: Evaluation in Classroom			
Activity: Implementation			
Role	**Task**	**A**	**B**
T	Prepare Learning activity to use along the game	X	X
	Prepare Learning materials to use along the game	X	-
	Prepare evaluation instruments to use along the game	X	-
L	Contact Schools for Implementation of the experience	X	X
	Set-up devices for the experience	X	X
	Set-up Physical aspects of the experience	X	X
	Print markers and other trackables for the AR experience	X	X
	Train Teachers in the ARGBL game	X	-
	Train students in the ARGBL game	X	-
Ds	Help on the Implementation of the product	X	X
Dv	Help on the Implementation of the product	X	X
R	Perform Diagnostic evaluations	X	X

Activity: Evaluation			
Role	**Task**	**A**	**B**
T	Perform Learning activity using the game	X	X
	Perform appropriate evaluations after the experience	X	X
L	Check and approve for Product Quality	X	X
Ds	Help on Evaluation of the product	X	X
Dv	Help on Evaluation of the product	X	X
R	Plan Evaluations during the research	X	X
	Perform observations	X	X
	Analyze results of the evaluation in classroom	X	X
	Report results	X	X
	Discuss results	X	X
	Perform De-Briefings	X	-
	Record Interactions	-	-
	Input results for Re-iterations	X	-
	Identify issues	-	-

The table shows all the tasks that were planned to accomplish. All of the tasks are done under the suggestions of Co-CreARGBL for each activity. Evidence on the completion of each of the tasks can be found documented in the recorded design sessions, the documents created by Teachers and Designers and the Assets created as the resulting games and experiences. The Researcher collected the documents for all of the tasks in a Google Drive account shared with all the members of the team.

A total of 123 tasks were planned, and while some of them were transversal (they were going to be applied along most of the activities in the process), such as Leader's "Check for Quality of the Product", they were divided for each activity were they were relevant. The table accounts for the quantity of the tasks that were completed, resulting in the completion of 88% of them by Team A and 82% of them by Team B.

Some of the activities were not completed due to the particularities of the process. For example, in the first Training Activities, Designers and Developers are supposed to "Help in the Training process". During the Training process, additional designers and developers had not joined the process yet, so these tasks were not done. Nonetheless, most of the non-done tasks were optional. For example, Teachers may or may not help building physical objects, which was done for Team A but not for Team B.

It is considered that the attribute of Completion gives a broad view on how the example case studies followed the suggested tasks by Co-CreARGBL and thus links the process to the method.

Attribute of Comprehension by the Teachers

As for the attribute of **Comprehension by the Teachers** the three interviews performed on each of the teachers were highly interested in understating the Teachers' level of comprehension on the method and the process conducted. A Thematic Analysis was conducted on the recorded interviews. There were three semi-structured interviews. The first one, done after the Training process ended, wanted to observe the level of understanding regarding the Training stage and the concepts seen during its activities. The second interview was done during the design process and wanted to observe their comprehension of Specification, Analysis and Design Activities. And the third interview was done after the Evaluation in Classroom stage, and observed their comprehension on the Evaluation process.

Next, the most relevant themes regarding the comprehension of teachers are described.

Comprehension of the Process' objective

During the first interview, Teacher's answers gave information about the comprehension they had about the process that had just started. The interview asked for deeper answers regarding their profiles as creative teachers: whether they had used playful strategies and/or AR. The interview asked about their motivations to participate in the process and what were their expectations with it, in order to know whether and how they understood its objectives and the problems that were being tackled by creating an ARGBL game.

The Thematic Analysis concludes that in general, Teachers are aware that the process is about creating a game involving AR technology and they seem to be related to both concepts. They understand that the objectives are, among others, create tools that help students to get motivated into the learning objectives chosen by the teachers. Other objectives include the inclusion of innovative ICT techniques for learning in the classroom and to propose a constructivist learning environment getting away from classical behaviorism (both concepts were explored during the training stage). Some of their assertions are:

> ***TA2:*** *I'm always looking for ways to keep students active…*
>
> ***TA3:*** *Things have changed a lot, and students are very active with ICT … They are not eager to learn with traditional strategies … I think games with AR are very useful for teachers as to gather children around learning…*
>
> ***TB1:*** *Strategies with games and learning allow knowledge not to be just filling an empty bottle; it allows that they themselves build their knowledge from their own emotional being*

Teachers also value the approach of working collaboratively to create the educational assets. This is mainly because they do not feel able to create digital resources themselves often because of fear and lack of knowledge.

> ***TA3:*** *I don't feel I'm able to create digital resources… With what we are doing here is that I'm just starting to learn.*
>
> ***TB2:*** *When you are teacher you face a strict curriculum, and thus, you have a fear of not accomplishing it, thus you don't use these tools that perhaps could be useful.*
>
> ***I:*** *Do you feel able to create educational resources…*
> ***TA4:*** *Honestly, analogic resources, yes, not so, digital resources… Because I know no tool to make a digital design… Because of ignorance (laughs)*

Teachers understand this was a process of iterative design and creation of playful resources.

> ***TA3:*** *I feel great [with the process] I think it is important how contributions from everyone are taken into account…*
>
> ***TA3:*** *At the beginning I thought it was not going to be done, but when we started writing and looking at possible flaws, what could be done, what could work, we contributed and at the end I think there is a meaningful advance in the game*
>
> ***TA2:*** *The game is a result of different ideas, maybe one had an idea and it was enriched with other contributions…*

Although in most cases teachers use indistinctly the terms "lúdico" (Spanish for "playful") and "didáctico" (didactic), they value positively the strategy that involves the game aspect and thus they find that the purpose of the process is justified. This positive valuing of the games also applied to AR:

> ***TB1:*** *Learning should be a way of feeling, and a way that it does not become an almost traumatic experience is the use of games…*
>
> ***TA2:*** *These strategies are a way to be at the level of the students*
>
> ***TA4:*** *…Social Sciences maybe a boring subject… I use these [didactic] dynamics so students retain the attention in class.*
>
> ***TA4:*** *I'd say that AR improves learning in our students… at a 100%... with this, we will get them to take what we want them to take [learning]… in a playful way, a more attractive and motivational way*

AS the interview is a semi-structured, the answers are heterogeneous, but they reveal that the teachers were aligned with the process' objectives.

Comprehension of the Training stage

The part of the first interview that asked for a summary of the Teachers' experience was used to analyze their comprehension of the Training stage. Also, the second interview started by asking teachers to mention uses and advantages they could have learned from the training stage and how they applied to the process they were conducting.

It is evident from their answers that Teachers do not express themselves using the formal terms used during the Training stage; rather, they express themselves with informal expressions, or "in their own words". Nonetheless, while not using formal terms, the Teachers' answers show, on one hand, that they understand and value the importance of the Training stage, which they called "capacitación" (a term in Spanish that is used in their local education department when they are sent for ongoing training or professional development).

> ***TA2:*** *[the training stage] is a strategy that helps… because it is hard to unlearn stuff you come with… [Here the teachers tells a story about how the training stage helps her to think off the box and to learn new things]*
>
> ***TA4:*** *[The training stage] is important, because it tells them [teachers] what are the uses of a game for learning*
>
> ***TB1:*** *What we did [during the training stage] was to recognize what was Augmented Reality…*

Some teachers, when summarizing the experience, do not mention the training stage as a part of the process. They skip this step, perhaps because they do not consider it as part of the design process but as a previous step.

Teachers consider that the design is supposed to be guided by a set of principles. During the training stage they saw some principles found in the literature. Teachers fail at declaring them, however on their own words teachers mention principles. For example teachers mention: *Understanding, Innovation, Motivation, Fun, Analysis of Educational Content, Avoid Behaviorism, Usability, Didactics, Playfulness, Stealth Learning, and Attractiveness* among others.

Regarding uses and advantages teachers mention*: Widening the learning process (to reach other subjects), engage students into subjects, Motivate students to learn, Innovate in the classroom, Playful learning,*

Remembering content, Visual impact, Agency, Autonomy and the ability of the student to get insight into learning objects among others.

Comprehension of the Iterative Design stage

During the second and third interview the activities of the Iterative Design and the Evaluation in Classroom stage were covered. Also, in the third interview Teachers were asked to express the step-by-step they would follow would they start a new process with other Teachers or Designers. The answers of the teachers show that they have a general understanding of this stage. They comprehend the process that was being conducted as an iterative process of design. However, as in the previous stage, teachers do not express themselves in the terms or concepts stated in the method, but, their answers evidence that they understand the general characteristics of the process.

Teachers value positively the process during their discourse. They think it is important that it is an iterative, collaborative and interdisciplinary process.

> ***TA4:*** *I think above all there is the design… before going to the game… The main thing is to design what we want to do, specify the learning object and then the game's objective which are very different*

> ***TA1:*** *When we proposed the contributions then we saw, whether that could work, or that would fail… If the idea was not pedagogical, or it wasn't aligned with the learning objectives then we adjusted it in order to modify it…*

> ***TB2:*** *Based on the information that was given (the educational content) they [the designers] created the design… but when we saw flaws or inconsistencies, we improved it.*

Teachers mention some specific activities, such as the Specification activity:

> ***TA4:*** *I think the specification activity was done when we conducted the Brainstorming activity to give ideas on what would be interesting to work… The start point was very different, but when we worked it took form…*

Teachers mention other aspects of the Specification activity such as: *Giving ideas, agreeing with the other teachers the learning objective, defining the learning objective, Check the contributions and improve them* among others. They also mention other tasks related to the Analysis activity such as: *Check the educational content to contribute ideas and Plan the design at a general level*.

It is recognizable from the answers that while teachers understand the characteristics of each task, they mix the tasks and they do not assign them to a particular activity. For example, tasks on the Specification activity are mentioned during the *Analysis* activity and/or the *Design* activity. Since the process was an iterative process, teachers were not required to hard-recognize the activity, but to work on the tasks which can lead to the confusion. Also teachers refer to the *Development* activity as "the design made by the engineers".

Some teachers mention terms proper of the design stage such as: *Character Design, Defining rules, Develop the Theme, Define Flow, Define Mechanics and Define Dynamics.*

Comprehension of the Evaluation in Classroom stage

During the third interview, the Teachers answered to questions about their comprehension of the Evaluation in Classroom stage which they had just finished. On these, it was evident how teachers comprehend the stage. In their answers while answering the step-by-step process teachers mention these tasks during the evaluation in classroom stage: *Correct the Design, Observe the learning outcomes,*

Implement the game with students in the classroom, Observe how students receive the game, and Evaluate the capacity of the game to reach the learning objective among others.

While most Teachers mentioned tasks relating to the Evaluation activity, few Teachers mentioned the Implementation activity and its tasks. However, they participated actively during these tasks (creating the evaluation instruments, for example). Teachers do not identify this part as a different activity. Nonetheless, the answers show how they understand that the process of taking the game and implement it in the classroom when they describe the other activities of this stage.

Teachers explain that during this activity the school was supportive and helped by allowing the students for the evaluation, and allowing the research to be done in the school. One teacher explains that *"… the school helped us when we explained to them that we were bringing an Augmented Reality tool and it was innovation for our school…"*

With this, the arguments for linking the usefulness of the product with the use of the method conclude. The arguments for the EPV conclude too. In this section it has been shown how the method was useful from several perspectives and how that accounts for building confidence on its performance in the case studies used.

6.2.4 ARGUMENTS FOR THEORETICAL PERFORMANCE VALIDITY (TPV)

It is argued that the TPV depends highly on the other validities shown and argued previously as it is virtually impossible to demonstrate validity for every case. Authors of the Validation Square explain how, for this type of method validation, it is acceptable to build confidence in this type of validity by observing the other validities in retrospective and deducting its general validity. Thus, in this section it is explained briefly, based on a deductive argument, how the method is expected to be valid for most cases on its domain of application, would it be used later with other, teams, technologies and/or learning objectives.

The TPV is considered to be acceptable after this validation process because the method has shown to have consistency. On one hand, the method is consistent with other methodologies of building Learning Resources with Games and with Augmented Reality. These methodologies and their aspects are called "parent constructs". The method is in many ways a re-structuring of those constructs and it considers many important aspects of the design and development of Learning Resources, such as the roles, the activities, the tasks and so on. On the other hand, the method has shown internal consistency by showing how the different stages and activities complement each other by offering the right information and requiring actors on the process to produce the information adequate for the game with AR. These aspects (discussed in section 6.2.1) propose the method as repeatable, given that future designers, Teachers and researchers become aware of the constructs proposed. Also, the flow of information allows future users of the method to have a canvas to follow in order to guide their process.

A set of two case studies were used to validate the method in real case studies. These case studies have been analyzed and validated from a theoretical and a performance point of view. With the arguments mentioned in the previous sections, it is seen how those case studies are adequate as they classify as acceptable problems where the method is to be used. This was discussed in sections 6.2.2 and 6.2.3. It has been shown how the method was useful for those cases and its usefulness seems to be linked to the application of the method. This is that the products obtained with the application of the method –An ARGBL game and accompanying experience–, were useful because they offered a good experience of learning to students while offering the right amount of educational content and allowing teachers to innovate in the classroom. Moreover, the resulting products would not have been possible without following the method's activities, stages, roles and tasks.

Results on the validation for the case studies used as example problems suggest that the method is useful in any scenario (under the domain of application) because as it was shown in section 6.2.2 the

example problems were useful to illustrate the general cases of application of the method. Thus, this suggest that given similar cases, future users of the method are able to repeat the results and outcomes of these processes.

Arguments for the general validity of the method have been already exposed. It only remains to warn future applications of the method to understand that the method is a general guide, and that the considerations are to be carefully decided by Leaders and Designers. Also, observe how the method is to be applied with teams comprising teachers that may or may not be used to the use of technology in the class, but that are willing to learn and design their own games and experiences involving games and AR.

Note that, the case studies in which the method was applied involved scarcely funded teams and Designers and Teachers that were participating voluntarily. Thus, while the method is intended to be used with teachers that are not fully funded and simple AR, better results are to be expected if the process is framed on a bigger project, perhaps more funded.

It is important also to remember that the theoretical performance of the method depends highly on the expertise of the Designers, the willingness of the Teachers and the capacity of Leaders to conduct the process. The method is intended for teams where Teachers are working together, but not by themselves; rather, it is thought to be applied in environments where a tight relationship between Teachers and Designers is feasible. Note also, how the method is intended for projects rather long, spanning months, it is not thought to be applied in short-term projects and simple quiz-like or authored games.

With these considerations in mind, and the thoroughly presented arguments shown in this section, the method is considered to be validated.

6.3 DISCUSSION

The results of the validation process mean that Co-CreARGBL is a suitable method to conduct a process of Co-Design that involves Teachers and Designers working to create an ARGBL experience for the classroom. The validation of the method has been conducted from the various perspectives involving the views of Teachers-Designers, Peer-Teachers, and the Students. Also, it has been viewed from the quality of the resulting products and the educational benefits.

Particularly, for this process, the case studies involved Teachers and Students in rural schools; which signified an additional challenge due to the more scarce availability of technology. However, even under these circumstances, there are some teachers that are willing to participate in Co-Design endeavors and they should be supported by schools to propose other learning objectives and other learning resources. For ARGBL Co-Design to be a reality, the Teachers have to be supported by Designers and Leaders. This way, there is a high chance that the resulting products involve the knowledge of the teachers of the educational content and the experience is fed with their knowledge of the students' context.

Other experiences in the past have shown ways to support teachers in the creation of games and/or AR experiences. This support is often in the form of an authoring tool or by treating teachers as mere informers. However, not many works have shown the work of teachers participating actively in the Co-Design of a game for learning (with or without AR). Thus, this experience shows that teachers can participate as creative actors in design endeavors that go beyond the limited results of, for example, an authoring tool.

This design experience shows that it is possible for teams to involve creative teachers and attain results that are more complex and professional with game mechanics tightly related to the educational content. The validation process also shows experiences were AR is not only used to display virtual

information, as many cases in the past have shown. In these experiences, AR is "playable" and its interaction is highly related to the learning experience.

Of course, there are some limitations for the method. For example, as the process is expected to be long, Leaders have to maintain the motivation and the willingness to work of the Teachers and Designers and the focus on the Learning Objectives. That is why the method relies on the expertise of the Leaders and Designers and their ability to motivate Teachers. Normally, Teachers will not have the creative skills developed, and thus they have to pass through a learning process similar to the ones described in previous experiences (Carroll et al., 2000). In this experience, it was seen how teachers started being shy, but from the training to the evaluation classroom it was seen how they passed through this learning process and how they matured their ideas as they interacted with the design team.

Co-CreARGBL is indeed similar to other methods of Learning Resources design. However, this method differentiates itself because it is guided by principles specifically related to games and AR. Also, the method is meant to guide long process of craftsmanship mediated by dialogue and in this sense, it has shown to be a benefit for teachers and students by providing ARGBL learning resources. This cannot help but to spawn the question on how teachers should participate in the creation of learning resources, if only as informers or as deeply involved creative actors. This thesis, based on this validation, proposes the latter.

Naturally, some aspects to improve are observed from the opinions of the Teachers. For example, Teachers seem to be not that aware of the names and structures of the activities and stages, which suggests that they should go through a training process of the method itself.

The resulting games have a high complexity and their definitive impact on the students should be observed on longer research endeavors. This study was focused on observing the teachers, while the games and their interaction with the students are only shallowly observed. Interesting observations should come from deeper observations and measurements of the students interacting with the games designed by their teachers and their following of the curricula.

If the validity of this method is accepted, then it shows the possibility of creating rather complex ARGBL artifacts with the participation of Teachers as creative actors. It also shows that the results of this creation is influenced by following a method that guides the process as a process of long craftsmanship mediated by dialogue and guided by principles.

6.4 CONCLUSIONS OF THE CHAPTER

In this chapter the arguments for the validity of Co-CreARGBL method have been shown. The Validation Square was used as a validation framework due to the characteristics of the process. This framework was chosen because it considers the validation of the method as a process of building confidence on its usefulness, and it understands the usefulness as whether the method provides design solutions correctly and with acceptable operational performances.

Several arguments have been presented throughout the chapter to support that the method has theoretical and empirical validity in both, structural and performance perspectives.

For the validation a set of Acceptance Conditions were observed, and for each of them arguments based on the data collected for the case studies presented in the previous chapter are described. Finally, the Theoretical Performance Validity of the method is discussed based on the previous validities. This final validity is meant to describe how the method is valid to be used in further experiences and applications.

While acceptance of the method and its validity remains on the consideration of further applications and readers, it is considered that it has fulfilled the criteria for validity and thus it works as a method to guide the process of Co-Designing ARGBL games with teachers.

Given this, the results of the validation process suggest that the method Co-CreARGBL is useful in guiding the design, creation and evaluation of ARGBL artifacts in the classroom. As it has been shown in previous chapters, the method is meant to guide teams of Co-Design that involve Teachers and Designers alike, and it is guided by principles related to Game-Based Learning and Learning with Augmented Reality.

PART FOUR: CONCLUSIONS

7 CONCLUSIONS

In this chapter the conclusions of the study are shown. The chapter shows the general summary of the thesis; it discusses its implications and shows conclusions for each of the two research questions and four objectives. Moreover, Limitations and Future work of the study are shown as open-issues to continue the research on the ARGBL field and other aspects related to this thesis.

7.1 RESULTS AND DISCUSSION

The main motivation for conducting this thesis was that there is still nowadays a lack of interactive systems that put the learner as the center of the learning process. However, some Teachers and some Researchers and Developers, are striving to propose, test and argue in favor of the use of Technology-Enhanced Learning (TEL) in order to overcome this issue. This thesis explores two of those technologies that are appearing in the classrooms: Augmented Reality and Game Based Learning joining the term under one: ARGBL.

This thesis has been a study and exploration on the use of Augmented Reality Games with Learning Objectives which led to proposing the concept of ARGBL as the union of AR and GBL. The thesis explores the use of ARGBL in the classroom and the creation and deployment of ARGBL experiences by collaborating with teachers. The thesis has identified prior works relating to ARGBL and has proposed theses and results regarding the impact of this technology in the classroom.

The thesis has discussed the concept of ARGBL, its relevant concepts regarding its use creation and evaluation of experiences. With this knowledge, ARGBL has been observed in action in naturalistic environments that comprise an exploratory scenario and a set of case studies designed and conducted with real teachers. The thesis has proposed and validated a set of technologies in the form of methods, theories, concepts and frameworks in order to guide the process of designing with teachers.

In this section the general findings of this thesis are discussed by referring to the Research Questions and Objectives proposed in chapter 1.

In order to answer **RQ1**: "*What implications are there in the use of ARGBL in the classroom?*", first a review of the state of the art and previous relevant concepts was done and then based on the concepts found, an ARGBL experience was designed and a design experiment was conducted in order to observe those implications. But also, given that the RQ1 is very broad, this question was answered during the validation of Co-CreARGBL which was done later because the validation used two example cases where the implications of using ARGBL were observed. These implications are discussed in the addressing of objective O4..

Addressing Objective O1: "*To conduct a literature review on the fields pertaining to the ARGBL field*"

Chapter 2 shows a state of the art on AR, GBL, ARGBL and their creation, which was able to identify some open issues to tackle. Among those open-issues it was found a lack of deep observations on the technology in action in the classroom and the lack of frameworks, design guidelines, and methodological approaches to guide their creation and deployment. ARGBL, being a relatively new technology for the classroom, still requires methods, explorations, and other approaches that structure the field. There is a need for theories and other observations that account for the characteristics of ARGBL experiences and their implications when they are being, created, used and evaluated.

This state of the art showed a recompilation of relevant theories and concepts that affected the vision and general understanding that guided the thesis. The state of the art included a revision on the concepts of AR, its characteristics and the aspect that define the application of AR such as the *Visual Display,* the *Device Category* and the *Tracking* techniques. This revision was done under a taxonomy inspired in previous research. Also, the applications of AR for Learning were reviewed, showing that there is a great interest in applying this technology in the classroom, that there are many researchers who support its application and also that there are still obstacles to overcome. Similarly enough, the GBL field was also reviewed, showing important authors and theories that guided this thesis. This review also showed that there are studies that support the advantages of applying games for learning.

In order to find what design approaches have been used to propose AR and GBL experiences for learning, the state of the art also showed a section regarding the authoring of these experiences. This showed that there exist many technologies that allow the creation of AR simple applications and some games for learning, but that are limited because they are aimed to be used by non-technical users (such as teachers).

In this order of ideas, it was necessary then to review the field of ARGBL, which as it is natural showed that are less studies that studies regarding AR and GBL. Of course this is due to ARGBL being a recent approach. The results of the review showed that not many experiences have been conducted on ARGBL, and the few ones did not include teachers on the design process.

Addressing Objective O2: "*To conduct an exploratory scenario allowing exploring the implications of using ARGBL in the classroom.*"

An exploratory scenario was conducted under the methodology of Design-Based Research (DBR) as shown in Chapter 3. The chapter discussed the design of an ARGBL game and a corresponding design experiment that allowed observing the game in action in a naturalistic environment (a class in a classroom). The game and the design experiment were conducted under the DBR approach because it was decided that the best way to observe the implications of using ARGBL in the classroom, should consider the classroom and its context.

The ARGBL used in the exploratory scenario was developed as an AR book, in which every page presents a scene (displayed in a mobile device tracking the illustrations of the book). Each scene presents a challenge to the reader, and this challenge can be surpassed by reading the book and comprehending it. The game was played by a set of students in an elementary school. Their actions when interacting with the game were analyzed qualitatively.

With the game and the design experiment, the exploratory scenario resulted in the identification of the actions enacted by the students and it is argued that the actions enrich the learning process as depicted in section 3.4. Among those actions the study has stated that the students were found *exploring, interacting with the partner, solving problems, stating hypothesis, testing hypothesis and collaborating with their companions.* These actions show that the experience of learning (with the learning objective of reading comprehension as it was the case study explored) is enriched by the use of ARGBL.

Nonetheless, in the same chapter a quantitative study was also conducted and it showed that in terms of the assessment on reading comprehension, students scored the same as those that did not use the ARGBL approach. Thus, it can be argued that the learning outcomes are the same when the reading is augmented and it is part of a playful experience. The ARGBL has shown to have advantages in the motivation of students as the students reported feeling more interested and enjoying more the experience as shown in section 3.4.

Among the disadvantages the study was able to find that some negative actions could be observed during the learning activity such as students *monopolizing the learning resources, avoiding collaboration and not following the learning process instructions.* The most important negative action was observed in students that focused their attention solely in the game and avoided the reading at all. It is argued that ARGBL for the case of reading comprehension may bring the disadvantage that students sacrifice attention to the reading for dedicating their time to solve the reading problems. Other negative issues on the use of ARGBL include the technological limitations that perhaps can be improved as technology shows better interaction techniques and AR recognizing and displaying techniques.

The exploratory scenario was also used to identify a set of lessons learned that helped to identify the needs for creating and deploying ARGBL experiences with teachers as shown in section 3.5. The lessons learned with the exploratory scenario revealed that the teachers are not familiar with the technologies and with the right application of AR and GBL for learning, and thus a process to guide them needs to consider this. It is argued that when it is desired to include teachers in the design process they need to recognize the tools and used of ARGBL not only as users but as creative actors, and that needs a process of training. The lessons learned also suggested that the process of creating an ARGBL experience should be i*terative, collaborative* and *including AR and GBL design professionals.* These lessons learned led the author of this thesis to think that the best way included a process that guided teachers to collaborate with designers and developers, which at the end benefits the most the resulting product by making it with the right complexity that aids the learning; it also, allows the teachers to relief the burden of creating the parts of the game. The other needs recognized state that the process should identify the advantages of AR and GBL for the learning objective, because, as seen in the exploratory scenario, not every game mechanic and technology favors every learning objective.

In order to answer **RQ2**: "*How to support teachers and designers in the design, creation and deployment of ARGBL artifacts and experiences?*" the results observed in the exploratory scenario were considered, then a methodological approach was proposed and then it was validated to show how to give support to teachers and designers in the endeavor of creating ARGBL experiences.

> Addressing Objective O3: "*To propose a set of methodological approaches that guide the process of creating and deploying ARGBL experiences involving teachers.*"

The identification of needs conducted in the exploratory scenario led to the proposal of a methodological approach instead of an authoring approach mainly because more complex games and experiences were needed, and as seen in the exploratory scenario, teachers may not be able to generate those kinds of experiences nor they have the time to completely create an ARGBL experience.

The method, called Co-CreARGBL, was proposed as a solution to the gap that exists between teachers and designers when designing learning experiences. On one hand, designers are not always aware of the learning contents and contexts needed to create a learning object such as an ARGBL experience. On the other hand, teachers often do no have the capabilities to understand the uses and advantages of AR

and GBL in order to build their own complex experiences. In this thesis it is argued that the methodological proposal works better than an authoring tool as seen in two case studies conducted were the results were far more professional and complex that what could be achieved by an authoring tool used by teachers in a short time.

Regarding the method it is argued also that the guiding process should be *long, guided by AR and games design principles* and *a process of craftsmanship.* These characteristics discussed in section 4.2 allow the teams to include teachers not only as informers but as active creative actors. The characteristics of the method also allow for more complex games and more complex interactive AR experiences that will benefit the learning process.

Co-CreARGBL, as discussed in section 4.1 is a method based in the paradigm of "Co-Design for Learning". This paradigm proposes that anyone can be creative, and it considers the participation of "practitioners" (Teachers, Students and other stakeholders) in the design process. In this sense, Co-CreARGBL is a method that advocates for designs promoted by professional designers of AR and GBL, but where the actual practitioners (the Teachers) and the final users (Students) act as designers providing their hindsight. In section 4.1 it is also shown what previous concepts, frameworks and theories (dubbed "parent constructs") were used in the proposal of Co-CreARGBL so as to give it validity as the parent constructs are considered valid and useful.

Section 4.2 shows the structure and recommendations of Co-CreARGBL. Simply put, Co-CreARGBL is a method that proposes a set of roles to be enacted by the participants. These roles are:

- **Leaders:** They lead and manage the project and account for its quality
- **Teachers:** They participate as creative actors and propose Learning Content and Learning Objectives
- **Designers:** They participate as creative actors by proposing ideas on AR and GBL aspects and they scaffold the Teachers' ideas.
- **Developers:** They construct the final product.
- **Researchers:** They account for the findings on the product, its design and the educational outcomes.
- **Students:** They are the final users of the product.

The roles, which can be enacted by several people in a team, are agreed by the participants and then they follow a set of stages and activities that are aimed to produce, deploy and evaluate the ARGBL experience. The stages and activities are as follows:

- **Training Stage:** Where Teachers are trained in AR and GBL by Leaders and Designers
    - *AR Activity:* Teachers are trained in AR
    - GBL Activity: Teachers are trained in GBL
- **Iterative Design Stage:** Where the creative work happens between Teachers and Designers. Here the Developers also create the product. This is an iterative process.
    - *Specification Activity:* Teachers propose the Learning Objectives and Learning Content that guide the creation of the ARGBL experience.
    - *Analysis Activity:* The Team analyzes the specification and they create a game idea.
    - *Design Activity:* The game is designed according to the Principles and Design Models stated by the Team.
    - *Development Activity:* The Team builds the product.
- **Evaluation in Classroom Stage:** Where the product is evaluated in a naturalistic setting with Students and Researchers perform their observations.
    - *Implementation Activity:* The product is taken to the classroom. Teachers design Instructional Activities and Evaluation Instruments. Researchers plan the observations.

- *Evaluation Activity:* The product (game and experience) is tested in a naturalistic environment.

The method also proposes other conceptual contributions. For example, it proposes a Framework for Generating an ARGBL game idea to be used in the *Analysis* activity. The framework consists in a set of canvases and steps that have to be followed by Teachers and Designers in order to propose a game idea, making use of the AR characteristics seen in the Training stage. Also, the method proposes a continuum to classify AR games as seen in section 4.2.3.

Chapter 4 also poses some general recommendations based on the case studies conducted to design and refine Co-CreARGBL method.

Addressing Objective O4: "*To validate the proposed set of methodological approaches in order to check their usefulness*"

In order to validate Co-CreARGBL, it was applied to two case studies as depicted in Chapter 5. The case studies comprised a set of six teachers who were described in the chapter and a set of professional designers in the process. The teachers and participants divided into two teams. The teams conducted the stages and activities of Co-CreARGBL and this resulted in the creation of two ARGBL games with accompanying instructional and evaluating activities. The games were evaluated in their execution within corresponding naturalistic environments.

The first team, Team A, worked in the creation and evaluation of a videogame with AR (as classified in the continuum proposed by Co-CreARGBL) aimed to Learning Objectives in the Social Sciences for students in elementary school. The game is described fully in section 5.2. Essentially, the game is an ARGBL game that includes a board map where Augmented Content appears. The map is from a region in Colombia: the department of Cauca. Team A designed a game where the student's objective is to lead "alien visitors" into the department. This can be done by using the AR "paddles" that the game offers and also students can use the Information System within the game to learn about the department.

Team A, on the other hand, worked on a Board Game with AR (as classified by the continuum proposed in Co-CreARGBL) aimed to Learning Objectives in Philosophy and Mother Tongue in an elementary indigenous school of the Nasa Culture in Colombia. The board game is an enactment of the traditional family values in the Nasa culture. The student's objective is to arrive to the "marriage" of the main characters according to the traditions of the community. The game can also be used to hear the pronunciation of common day objects in the *Nasa Yuwe* language and it can be used to get to know about the lunar calendar of the Nasas.

The case studies were used as example problems in the validation process which was done using the validation framework known as "The Validation Square" as presented in chapter 6. The Validation Square proposes that validating a method is building confidence on its usefulness. Thus, arguments were presented for each of the Acceptance Conditions presented by the framework. Co-CreARGBL was observed from several perspectives during the validation process. Arguments were presented about the consistency of Co-CreARGBL, the adequacy of the example problems used (the case studies), its usefulness, the relationship of the usefulness to Co-CreARGBL and the general validity to be applied in other scenarios. Under these arguments it is argued that Co-CreARGBL is useful and it is able to guide teachers and designers to propose motivating and useful ARGBL learning experiences that can be tested in the classroom.

The arguments of the validation process are presented in this document and in other publications. If the method is considered as valid it builds confidence not only in its structure but in the approach of including teachers when building complex games that use Augmented Reality. In fact, the state of the art in this thesis, and many works from the literature on AR and GBL have shown a tendency on proposing to the Teachers, software applications, authoring tools and other mechanisms to propose and create their own AR experiences or games for learning. Nonetheless, most of the time, due to the

constraints in technical capabilities, expertise and time, Teachers are not able to create complex experiences that take to the classroom the Game-Based Learning approach which not only proposes the use of simple games but more complex experiences that allow for an authentic platform for learning. In this sense, the validation of the method presented and the two case studies are an empirical example that can guide and inspire future studies and developments. Under the results of the validation process it is stated that the methodological approach of guiding teachers and designers to Co-Design ARGBL innovations results in products that are far from what can be achieved by teachers working alone.

While O4 was initially planned to answer RQ2 only, the execution of the case studies was useful to answer the RQ1. Since this question asked "*What are the implications of using ARGBL in the classroom?"* and the case studies where actual implementations of ARGBL in real environments, these implications were observed. First, as it was shown in Chapter 6, the use of ARGBL may benefit the learning activity by motivating students and by leveraging Learning gains mainly in the form of interest and engagement with the learning content. These findings help to support the findings of the exploratory scenario which concluded in similar results. Moreover, chapter 6 shows also the insights into the Teacher's opinions and their work with designers which is thoroughly discussed in the validation process and the observations of the "Satisfaction and Comprehension by the Teachers". Teachers are an important part of the implications of using ARGBL in the classroom because they are to be considered as the enactors and guides of the learning process helped by the gaming activity. Thus, these observations helped to understand, among other insights, that Teachers are able to participate as creative actors collaborating with professionals; Teachers become a central part of the process and while they cannot work in the same level of formality than Designers, they use their own word to describe and help during the collaborative work. Also, the executions of the naturalistic scenarios, Teachers were active participants of the evaluation, showing on one hand that they were able to conduct the ARGBL experience (albeit with some help from Researchers) and on the other hand, that they saw value on the ARGBL activity.

The previous discussion and observations show that ARGBL has advantages for learning and that its inclusion in learning settings is nowadays feasible. It is noteworthy that this is not exempt from particular considerations and obstacles, but the author thinks that these will be overcome with future developments and studies.

7.2 LIMITATIONS OF THE STUDY

It is important to recognize that the answers and results discussed in this chapter have some limitations. During the study of the exploration scenario that was used to accomplish objective O2 and the answering of answer RQ1 a case study was selected on the premise that it represents a part of the use of ARGBL. Nonetheless, ARGBL has various types which can vary depending on the types of tracking, devices and other aspects and thus, the implications shown in the chapter may vary for different configurations on the ARGBL experience. The exploratory scenario was conducted under the learning objective of promoting reading comprehension; other subjects and or learning objectives may present similar results, but they may also present other aspects.

It is argued that some of the observed actions can be generalized; however, some of the actions may not be present during other types of ARGBL experiences. For example, *reading the book* will not be present when the game does not include an AR book or a readable object; however, similar actions that relate the students with a real object in the ARGBL experience may be had in mind. In any case, the conclusions from the chapter should understand the particular case study explored and consider it as such.

During the application of ARGBL learning experiences on classrooms, it is important to recognize that the results depend also on the preparation of the person who acts as guide (teachers, researchers, parents, etc.). This is because the guides should understand the learning aspects of the experience, the technologies used and other important aspects in order for the student to profit the most on it. This is a

natural limitation given that ARGBL games are relatively new tools to be used in the classroom and most teachers will not be as prepared as desired. Each day more and more teachers are learning about new technologies, a small amount of teachers are very prone to learn on newer technologies and approaches, and thus those teachers are ideal to continue these efforts of including ARGBL in the classroom.

Regarding RQ2: "*How to support teachers and designers in the design, creation and deployment of ARGBL artifacts and experiences?*" the method proposed is limited to the intended uses as defined in section 4.2.1. It is thus, considered that the cases studies and the validation of the method was done explicitly in cases that belong to the domain specified by the intended uses. The intended uses, however, were defined observing the needs identified in the exploratory scenario and thus this limitation is natural and justified. Nonetheless, the answer to question RQ2 which asks about the way of supporting ARGBL should be understood in terms of this domain defined by the intended uses. It is still important to recognize that other studies and future developments may consider other applications or interpretations of ARGBL, for example other studies may understand it as strictly Location –Based AR games, rapid games created in a short-time with an authoring tool or Gamification experiences in the classroom.

The validation of the study was also limited to the case studies used as example problems. These case studies were conducted with teachers with no experience in the realm of AR and GBL, and thus, the validation should be understood with this constraint. In this sense, there is still a need to design other artifacts and perform other case studies using the method to broaden its validity.

Also, the case studies show argument in favor of the ARGBL method and the Co-Design of the experiences with Teachers. Nonetheless, the arguments and the data analysis, while showing comparisons between the ARGBL approach and other traditional approaches, is not meant to be comparative. The assessment of motivation was done using a validated test, nonetheless, the amount of students is not very high to be conclusive, this is proper of naturalistic studies such as the ones conducted here, where bigger scenarios would prove to be more complex and thus, more difficult to gather the data. Also, the assessment on learning gains used was not done with standard test as the aim was not to test the students at a very objective level (considering that the assessment was done only after a session with them) but to be a view from the perspective of the teachers and the assessment methods they use day-to-day.

With this in mind, it has to be understood that this study proposed a way to help Teachers and Designers to design and develop ARGBL games jointly. Nonetheless, more studies into the use of the products created are needed because proponents of these technologies and approaches are considering that a real impact could be done after the application of the experiences in longer periods and embedded into longer learning processes interacting with other techniques. This is far from the reach of this study, but, of course, this study leads future studies in this sense.

Finally, it is considered, that in general, technical and technological limitations may be surpassed with a general acceptance of the technology and its appreciation as a learning asset. While other limitations such as the particular characteristics of the case studies used are a natural restriction given that the method proposed is meant to be conducted during long processes of design and the restrictions of time on this thesis study.

7.3 CONCLUSIONS

In this thesis an argument is given in favor of the use of ARGBL experiences in the classroom. The argument is based on an exploratory scenario and a set of case studies designed under a methodological approach that guides the work of teachers and designers.

First the thesis has presented a state of the art on the issue of ARGBL, presenting literature findings on AR for education, Game-Based Learning and the union of both. The state of the art shown in chapter 2 shows also a special interest in the ways that AR for education and GBL have been created to be introduced in classrooms. This special interest came from the desire to get to know previous experiences and inspire a process for Teachers and Designers to include ARGBL in the classroom in an effective way. The state of the art explored various approaches, in particular the creation of AR and GBL experiences using authoring tools. A survey was conducted in order to find how many experiences in the past had included collaborative efforts including Teachers in the design, development and deployment processes; but, few were found. The state of the art concluded by mentioning that few experiences had included Teachers to develop ARGBL experiences, but that however this should be supported. Moreover, some open-issues were described among which the need for design methods that include different stakeholders and the need for studies to describe the insights and outcomes of using ARGBL in the classroom. The findings of the survey conducted was published in (H. Tobar-Muñoz, Fabregat, et al., 2017)

Later, the thesis designed, and conducted an exploratory scenario that was shown in chapter 3. This exploratory scenario used a specifically tailored ARGBL game for the learning objective of reading comprehension. The exploratory scenario was designed, conducted and analyzed using the Design-Based Research paradigm. This thesis subscribes to the postulates of the DBR paradigm by planning the research aiming to observe the designed artifacts under "design experiments" i.e. experiments where a particular design is testes and observations are gathered on its outcomes during naturalistic environments. The paradigm proposes the context of the study to least controlled as possible, as to observe the artifact (in this case, the ARGBL experience) in its natural state. Due to this, the study was not aimed to gather objective measurements but to observe the ARGBL experience and the interaction of students with it during an educational activity. This said, the outcomes of the study showed quantitative and qualitative results as well in order to be useful for future studies.

It can be concluded based on the observations, results and analyses showed within the exploratory scenario that ARGBL is a technology relatively new, generally unknown by teachers and by most students and thus it must be taken to the classroom with the right precautions. However, when this technology and its accompanying teaching approaches (such as learning and evaluation activities) enter the classroom, the thesis has shown that they have a benefit in the motivation of the students and in some cases in the learning outcomes.

The exploratory scenario helped in the exploration of the aspects to be considered when designing and ARGBL experience for the classroom which was reported, at the end of the chapter, in the form of a postmortem. The postmortem later fed the definition of a methodology aimed to include ARGBL in the classroom.

Based on the observations conducted in this exploratory scenario, it can be concluded that ARGBL enriches the process of learning by promoting the improving of soft skills while promoting collaboration, problem-solving, and other important skills that are part of the integral education of young learners. Nonetheless, it has also been considered that ARGBL is not a silver bullet, and as most artifacts that are designed for learning they have to be applied adequately according to their characteristics, the characteristics of the students and the context. The exploratory scenario was published in (H. Tobar-Muñoz, Baldiris, et al., 2017).

In this sense, since ARGBL experiences are considered valuable for learning scenarios but, there is a need to design them and deploy them adequately a method for designing ARGBL experiences with teachers has been proposed. The method, called Co-CreARGBL, is a tool to be used by teams that include teachers and designers that collaborate to create an ARGBL experience. The method is thought to be used on long process of craftsmanship mediated by dialogue between teachers and designers. This methodological approach which includes a method with a defined set of stages, activities, roles and

frameworks is meant to be used within a process that includes teachers not only as informers but as creative actors.

Chapter 4 described Co-CreARGBL thoroughly by proposing the roles, stages and activities that ought to be followed by its users. The method is centered around the concept of Co-Design for Learning (Roschelle & Penuel, 2006) because it aims to propose a set of steps for Teachers and Designers of ARGBL to collaborate in the endeavor of creating and deploying ARGBL experiences. The method is based on constructs found in the literature such as the traditional ADDIE model for its general structure (Branch, 2010), the roles proposed by the Six-facet model (Marne et al., 2012) and other special attributes, principles, and properties that come from the AR and GBL literature review. The method general structure was published in (H. Tobar-Muñoz, Baldiris, et al., 2016a, 2016b)

Once the method was proposed it was necessary to validate it. Thus, a set of case studies were conducted following the method with a set of teachers from rural schools in Colombia. In chapter 5 a description of the case studies is shown. The case studies show the description of the Teachers who participated, the activities followed using Co-CreARGBL with a brief description narrating every activity conducted by Teachers and designers. Also, the chapter shows a description of the products created within the two cases studies. These products were ARGBL games and accompanying experiences tailored to learning objectives in Social Sciences and Indigenous Philosophy. The games and the experiences held with teachers were published in (Hurtado et al., 2016; López Panesso et al., 2016).

The validation of the method as a method for designing ARGBL game experiences was conducted using the "Validation Square" framework (Seepersad et al., 2006). The framework proposes a series of arguments that ought to be given when validating a design method. Chapter 6 shows these arguments using as a base the case studies described above. The method proved to be useful as this process resulted in products that were feasible to use and useful for the motivation and learning outcomes of the students. The validation process presents arguments to build confidence on the usefulness of the method. With these arguments, it can be concluded that a methodological approach to design and deeply ARGBL learning experiences is a good solution to support the creation of ARGBL experiences for the classroom.

Finally, this thesis hopes to be another effort in the study of the application of AR and GBL as technological and pedagogical approaches in the classroom. This thesis shows the insights of using ARGBL and sheds some light in the endeavor of creating and using ARGBL experiences for the classroom.

7.4 FUTURE WORK

In this section some future works are presented. These future works are based on open-issues that this research leaves that at the same time are opportunities to continue the work in the field of ARGBL.

Of course, as has been explore previously, this study was a deep observation of just a few set of case studies that represent only a part of what could be considered ARGBL. Thus it is natural, that more and more studies should be conducted perhaps considering the theoretical bases that have been described in this thesis. Future ARGBL designs can help improve the scholar knowledge on the implications of using AR and GBL in the classroom.

Future studies may also contribute with design guidelines based in the results and observations of the studies presented here and other studies. While it is easy today to find in the literature all sorts of design guidelines and recommendations to build AR applications for learning or games for learning, it is not that easy to find guidelines when considering AR and games at the same time. Such a study may consider the experiences shown here as empirical evidence of the implications on using ARGBL and thus conclude on recommendations for even further studies. For example, as it was not considered in

this study, future works may verse on the psychological and cognitive impact of games an AR (used apart) and compare them to the impact of ARGBl to fully conclude what aspects are working on each approach in benefit of the students.

Novelty effect, as discussed in section 2.4, maybe a hindrance in the use of ARGBL because perhaps the motivation presented in the first uses of the game with AR are just because of the eye-candy of the game or due to the educational technology being new. ARGBL games should take this into account, and design the experiences to be used for longer times. To study this and conclude firmly on what is the actual novelty effect on the use of ARGBL, longitudinal studies should be carried out.

The proposed method may be refined. it can be refined by an inclusion as an integral part of it of the design guidelines abovementioned. In its current form, the method proposes a process guided by design principles and recommends a series of considerations to this end. Nonetheless, the method could be better informed and its participants better suited would the method propose specific guidelines for ARGBL. For this, of course, the design guidelines themselves should be tested.

The work of validation may also be improved with future iterations. Since the validation framework used to validate the method is a holistic method that presents arguments in order to build confidence on the method's usefulness, it is to expect that further applications of the method may the result useful, will improve the validation. These applications of the method may used the opportunity to use the method to build the ARGBL experiences for other scenarios, types of games of AR, educational content or other characteristics. It is noteworthy, that the application of the method was conducted with teachers not trained in AR or GBL at the beginning of the process. One aspect that could be interesting would be to apply the method with the help of those teachers, because the process will benefit from the experience of them and the training they have already received. Also, other variations to the method validatoins would be to use authoring tools, where the teams do not have access to design and development proffesionals.

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APPENDIXES

APPENDIX A. ARTICLES CLASSIFICATION

The classification considered to obtain statistics shown in Chapter 2 is shown here.

The works were classified as shown in Table. 1

For space saving purposes the following codes have been used:

ALK12	(Al-Khalifa & Al-Khalifa, 2012)
ARV09	(Arvanitis et al., 2009)
BAN12	(Banu, 2012)
BAR12	(Barreira et al., 2012)
BLU12	(Blum et al., 2012)
BRE13	(Bressler & Bodzin, 2013)
BUC09	(Buchau, Rucker, Wössner, & Becker, 2009)
CAM11	(Campos & Pessanha, 2011)
CHEN15	(C.-H. Chen et al., 2015)
CUE13	(Cuendet et al., 2013)
DONG13	(Dong et al., 2013)
DUN08	(Dunleavy et al., 2008)
ELS11	(El Sayed, Zayed, & Sharawy, 2011)
FER05	(Ferdinand & Ritschel, 2005)
FUR15	(Furió et al., 2015)
GOM14	(Gomes et al., 2014)
GUE14	(Guenaga et al., 2014)
JOH13	(Johnson & Sun, 2013)
JUA08	(Juan & Beatrice, 2008)
JUA11	(Juan et al., 2011)
HOD14	(Hodhod, Fleenor, & Nabi, 2014)
KIR12	(T. G. Kirner, Villela Reis, & Kirner, 2012)
KLO08	(Klopfer & Squire, 2008)
KLO10	(Klopfer & Sheldon, 2010)
LEE08	(H. Lee, 2008)
LEE09	(S. H. Lee & Choi, 2009)

LIM13	(Lim & Lee, 2013)
LIN11	(Lin et al., 2011)
LIU13	(Liu & Tsai, 2013)
LOG11	(LogicalChoiceTech, 2011a)
LOG11-a	(LogicalChoiceTech, 2011b)
MAR09	(Marco, Cerezo, & Baldassarri, 2009)
MAR10	(Martín-Gutiérrez et al., 2010)
MAR13	(Martinez, Díaz, Barroso, González, & Anton, 2013)
NIS07	(Nischelwitzer, Lenz, Searle, & Holzinger, 2007)
NUÑ08	(Nuñez, Quirós, Nuñez, Carda, & Camahort, 2008)
OSH11	(O'Shea et al., 2011)
PAR12	(Parhizkar et al., 2012)
PBS12	(PBSKids, 2012)
ROS07	(Rosenbaum et al., 2007)
SAL12	(Salmi et al., 2012)
SCH12	(School in the Park, 2012)
SHE04	(Shelton & Stevens, 2004)
SIN09	(Sin & Zaman, 2009)
SQU07	(Squire & Jan, 2007)
SQU10	(Squire, 2010)
STE12	(Stewart-Smith, 2012)
TAR13	(Tarng et al., 2013)
TEN12	(Teng & Chen, 2012)
TER12	(Ternier et al., 2012)
TER12-a	(Ternier et al., 2012)
THE07	(Theng et al., 2007)
TOB14	(H. Tobar-Muñoz, Baldiris, et al., 2014)
WAN13	(Y.-S. Wang et al., 2013)
WOJ13	(Wojciechowski & Cellary, 2013)
YAM(1)	(Yamabe & Nakajima, 2013)
YAM(2)	(Yamabe & Nakajima, 2013)
YAM(3)	(Yamabe & Nakajima, 2013)

Table. 1. Literature Review Classification – AR for Learning Experiences

	WOJ13	TAR13	DONG13	NIS07	THE07	LIM13	BAN12	SHE04	NUÑ08	MAR10	OSH11	BLU12	KIR12	PAR12	ALK12	TEN12	BUC09	ARV09	SIN09	LEE09	JUA08	ELS11	LIU13	STE12	SCH12	ROD15	CHI14	CUE13	
Optical See-Through																													0
Video See-Through	x	x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			25
Spatial(Projective)									x																			x	2
GUI											x																		1
Geo-Located AR											x																		1
Geo-Located AR with Orientation		x																					x						2
Movement-based																		x											1
Marker-based	x		x	x	x	x		x	x	x			x			x	x		x		x	x		x		x		x	17
Image-Recognition							x					x		x	x										x		x		6
Pattern-Recognition																				x									1
QR-Code Scan																x													1
Other																													0
Spatial	x			x		x	x		x	x		x	x			x	x		x	x		x	x				x	x	16
Headmounted			x		x			x										x			x								5
Mobile		x									x			x	x										x	x	x			7
Not clear																													0
Early childhood education															x														1
Primary education	x	x		x	x		x						x		x					x	x					x			10
Lower secondary education				x		x															x					x			5
Upper secondary education														x			x							x		x			4
Post-secondary non-tertiary education																													0
Short-cycle tertiary education			x																					x					2
Bachelor's or equivalent level			x						x	x						x	x						x	x					7
Master's or equivalent level			x													x													2
Doctoral																													0
Informal Learning																	x	x	x						x				4

	WOJ13	TAR13	DONG13	NIS07	THE07	LIM13	BAN12	SHE04	NUÑ08	MAR10	OSH11	BLU12	KIR12	PAR12	ALK12	TEN12	BUC09	ARV09	SIN09	LEE09	JUA08	ELS11	LIU13	STE12	SCH12	ROD15	CHI14	CUE13	
Any																				x		x				x			3
Not mentioned in the study								x				x		x															3
Educational																													0
Humanities & Arts						x														x			x	x					4
Social Sciences Business and Law																													0
Science	x	x		x	x		x	x	x				x				x	x	x	x									15
Engineering, manufacturing and const.			x							x						x	x												4
Agriculture					x																								1
Health and welfare				x								x									x					x			4
Services and Others																													0
Any																						x			x	x			3
Not mentioned/Clear														x	x														2
Exclusively Engineered by low-level		x				x	x		x		x	x				x	x	x	x	x	x	x				x	x	x	16
Engineered by Designers using mid-level			x																										1
Authored by Designers using Authoring															x														1
Authored by Designers helped by Eds.					x															x									2
Full-Collaborative effort																										x			1
Authored by Educators helped by des	x					x																							2
Exclusively Authored by Educators																													0

	WOJ13	TAR13	DONG13	NIS07	THE07	LIM13	BAN12	SHE04	NUÑ08	MAR10	OSH11	BLU12	KIR12	PAR12	ALK12	TEN12	BUC09	ARV09	SIN09	LEE09	JUA08	ELS11	LIU13	STE12	SCH12	ROD15	CHI14	CUE13	
None of the above																													0
Commercial																													0
Not clear								x						x									x	x	x				5

Table. 2. Literature Review Classification -AR and Games for Learning Experiences. (X = In literature, * = Commercial)

	KLO08	ROS07	SQU07	CAM11	KLO10	SQU10	LIN11	LEE08	MAR09	LOG11	LOG11-a	JUA11	PBS12	TER12	TER12-a	BAR12	WAN13	BRE13	JOH13	YAM13(1)	YAM13(2)	YAM13(3)	MAR13	DUN08	GOM14	GUE14	FUR15	CHEN15	TOB14	HOD14	
Optical See-Through																															0
Video See-Through				X			X	X	X	*	*	X	*			X	X						X		X	X	X	X	X	X	14
Spatial(Projective)																			X	X	X	X									4
GUI	X	X	X		X	X								X	X			X						X							9
Geo-Located AR	X	X	X		X	X								X	X									X							8
Geo-Located AR with Orientation																															0
Movement-based																															0
Marker-based				X			X	X	X			X	*			X	X						X		X	X	X	X	X		13
Image-Recognition										*	*								X	X	X	X								X	5
Pattern-Recognition																															0
QR-Code Scan																		X													1
Other																															0
Spatial				X			X	X	X	*	*					X	X		X	X	X	X			X	X		X	X		14
Headmounted																															0
Mobile	X	X	X		X	X						X	*	X	X			X					X	X			X			X	13
Not clear																															0
Early childhood education				X				X	X	*	*												X						X		5
Primary education			X					X		*	*		*			X	X		X						X		X	X		X	9
Lower secondary			X			X												X	X					X							5
Upper secondary	X	X	X																X												4
Post sec. non-Tertiary																															0
Short-cycle tertiary							X																								1
Bachelor's or equivalent	X		X				X								X											X					5
Master's or equivalent																															0

	KLO08	ROS07	SQU07	CAM11	KLO10	SQU10	LIN11	LEE08	MAR09	LOG11	LOG11-a	JUA11	PBS12	TER12	TER12-a	BAR12	WAN13	BRE13	JOH13	YAM13(1)	YAM13(2)	YAM13(3)	MAR13	DUN08	GOM14	GUE14	FUR15	CHEN15	TOB14	HOD14	
Doctoral																															0
Informal Learning					X		X			*	*	X	*	X					X	X	X	X									8
Educational																															0
Humanities & Arts															X	X									X						3
Soc. Sci. Business and Law																															0
Science	X	X	X	X	X	X		X		*	*		*					X					X	X			X	X	X	X	14
Eng. Manuf. & construct.							X																			X					2
Agriculture									X																						1
Health and welfare																			X												1
Services and Others												X		X			X			X	X	X									6
Any																															0
Not mentioned/Clear																															0
Exclusively Engineered by low-level Programmers/Designers	X	X						X	X			X					X		X	X	X	X	X	X	X	X	X	X	X	X	18
Engineered by Designers using mid-level tools							X																								1
Authored by Designers using Authoring tools														X				X													2
Authored by Designers with the help of Educators	X														X			X													3
Full-Collaborative effort				X												X															2
Authored by Educators with the help of designers																															0
Exclusively Authored by Educators																															0
None of the above										*	*		*																		0
Commercial			X			X																									2
Not clear	X	X						X	X			X					X		X	X	X	X	X	X	X	X	X	X	X	X	18

APPENDIX B. DETAILS ON ARGBL WORKS SURVEYED

(Rosenbaum et al., 2007)	**Classification**	**Content**	**User Study**
Description: A game where the players must stop a bird-flu disease from spreading across the institute **Technologies**: PDA **Authored:** No	**Tracking**: Geo **Display:** GUI-Map **Dev. Category**: Mobile **Collaborative: Yes** **Competitive: No** **Individual**: **No**	The game is a participatory simulation for teaching aspects of an outbreak, in particular, the avian flu. **Subject Matter**: Science	**Sample size: 21** **Time of Treatment:** One Session **Time of Session:** One afternoon **Method:**
Comments and recommendations: The study is interesting in that it explored a not so known concept of "Participatory Reality" which goes beyond AR and that not only sees AR as a technology. Nonetheless, the term his hardly seen nowadays. Also this was when GPS technology was not very advanced. Also, it is solely a location based experience which used Wi-Fi.			
(Squire & Jan, 2007)	**Classification**	**Content**	**User Study**
Description: A game to engage students into scientific thinking **Technologies**: PDA **Authored:** No	**Tracking**: Geo **Display:** GUI-Map **Dev. Category**: Mobile **Collaborative: Yes** **Competitive: No** **Individual**: **No**	The content in this experience is about the scientific argumentation. Students have to solve the case of a death in a lake. **Subject Matter**: Science	**Sample size: 12** **Time of Treatment:** One Session **Time of Session:** One afternoon
Method: Qualitative Design-based research. Students used the system and then they were interviewed.			
Comments and recommendations: This is a location-based only AR game. Also it is too old now.			
(Klopfer & Squire, 2008)	**Classification**	**Content**	**User Study**
Description: A game for learning about environmental decisions **Technologies**: Windows-Mobile Pocket PC **Authored:** No	**Tracking**: Geo **Display:** GUI-Map **Dev. Category**: Mobile **Collaborative: Yes** **Competitive: No** **Individual**: **No**	The game is a simulation about the case of a toxin in the environment. Players must solve the case and report back to the president. This is done mainly interacting with the game contents that include information about scientific facts and aspects relative to the case itself. **Subject Matter**: Science	**Sample size: 25** **Time of Treatment:** **Time of Session**

<table>
<tr><td colspan="4">Method: Design-Based-Research</td></tr>
<tr><td colspan="4">Comments and recommendations: This study is very old for now and it considers AR just as location GPS based. But it is a pioneer study on the application of AR games to education that can be inspiring and fostered nowadays. The study is simple for nowadays technology because of the devices we have now. Some properties and outcomes of this study are today recognizable and usable. The methodology and technological suggestions are to be used.</td></tr>
<tr><td>(Dunleavy et al., 2008)</td><td>Classification</td><td>Content</td><td>User Study</td></tr>
<tr><td>Description: An exploration of features of AR in Math, Arts and Literature educational settings
Technologies: PDA
Authored: No</td><td>Tracking: Geo
Display: GUI-Map
Dev. Category: Mobile

Collaborative: No
Competitive: Yes
Individual: No</td><td>The game is meant no to teach math, language arts and scientific literacy. However it is not a traditionally given content. The game proposes a participatory simulation in a role playing game where the students have to solve the case of aliens coming to earth.

Subject Matter:</td><td>Sample size: 80
Time of Treatment: 100 hours
Time of Session: Short</td></tr>
<tr><td colspan="4">Method: Authors used questionnaires, surveys, field notes, videotapes in a design-based research environment.</td></tr>
<tr><td colspan="4">Results: High motivation, engagement and collaboration</td></tr>
<tr><td colspan="4">Comments and recommendations: This is a highly cited paper. It is in the same line of participator, place-based simulations with location-based AR. It considers AR only as location-based, the study was done in 2006-2007 with out of date equipment. This study observes teachers which is very important.</td></tr>
<tr><td>(H. Lee, 2008)</td><td>Classification</td><td>Content</td><td>User Study</td></tr>
<tr><td>Description: A Mathematical Educational Game with AR. It is a Board game which uses markers to display important elements in the game and a set of marker-based die
Technologies: ARToolkit
Authored: No</td><td>Tracking: Geo
Display: GUI-Map
Dev. Category: Mobile

Collaborative: Yes
Competitive: Yes
Individual: No</td><td>The game is intended for the practice of addition and subtraction. It is based on a board game.

Subject Matter: Math</td><td>Sample size: -
Time of Treatment: -
Time of Session: -
Method: -</td></tr>
<tr><td colspan="4">Comments and recommendations: The game seems interesting and authors claim that the AR feature will increase the usability and learnability of an already available Board game and its computer game version. However the study does not show an evaluation or validation process.</td></tr>
<tr><td>(Marco et al., 2009)</td><td>Classification</td><td>Content</td><td>User Study</td></tr>
<tr><td>Description: This is an AR console. Authors show the development of the console which contains a tabletop system with tangible toys. The toys are the interaction medium and they are shown in the screen representing virtual elements.

Technologies: PC, Projector, Webcam, Maxine

Authored: No</td><td>Tracking: Marker
Display: Video/Projective
Dev. Category: Spatial

Collaborative: No
Competitive: Not Clear
Individual: Yes</td><td>The game is intended for early childhood education. It is a game about the farm animals.

Subject Matter: Animals</td><td>Sample size: -
Time of Treatment: -
Time of Session: -</td></tr>
<tr><td colspan="4">Method: SEEM - The structured expert evaluation method</td></tr>
<tr><td colspan="4">Comments and recommendations: Authors recommend that It is important that the children understand the goals of the game. However, giving to much details and instructions rests fun as they would only follow the steps. Letting them to explore and discover enhances fun and thus, learning.
- In this freely conditions, feedback (sound and georeference) is crucial, enabling the children to know in every moment if they are doing right or wrong</td></tr>
<tr><td>(Squire, 2010)</td><td>Classification</td><td>Content</td><td>User Study</td></tr>
</table>

Description: This is one of the classical examples of AR location-based Participatory simulations of Squire and company. Sick at South Shore beach is a game where players have to investigate the cause of epidemics. **Technologies**: - **Authored:** Not clear	**Tracking**: GUI-Map **Display:** GUI **Dev. Category**: Mobile **Collaborative: No** **Competitive: No** **Individual**: No	The game's content is meant to teach about environmental situations and scientific reasoning and inquiry. **Subject Matter**: Science	**Sample size:** 35 **Time of Treatment:** Two Weeks **Time of Session:** One afternoon
Method: The students played the game and the researchers conducted several tests.			
Results: Children liked more the AR game. The AR game enacted more sense of presence.			
Comments and recommendations: The paper is from 2010, but The experience was held in 2006-2007 it is out of date right now. It is an important theory oriented paper though. Also, they consider AR games as place-based experiences this is, they consider AR as location-based exclusively.			
(Klopfer & Sheldon, 2010)	**Classification**	**Content**	**User Study**
Description: This is one of the classical examples of AR location-based Participatory simulations of Klopfer at the MIT. In TimeLab2100 students have to work collaboratively to solve problems related to the environment. **Technologies**: - **Authored:** Yes, by students.	**Tracking**: GUI-Map **Display:** GUI **Dev. Category**: Mobile **Collaborative: Yes** **Competitive: No** **Individual**: No	The game's content is meant to teach about environmental situations and scientific reasoning and inquiry. **Subject Matter**: Science	**Sample size:** N/A **Time of Treatment:** N/A **Time of Session:** N/A
Method: The students played the game and the researchers conducted several tests.			
Results: Children liked more the AR game. The AR game enacted more sense of presence.			
Comments and recommendations: The paper is from 2010, but The experience was held in 2006-2007 it is out of date right now. It is an important theory oriented paper though. Also, they consider AR games as place-based experiences this is, they consider AR as location-based exclusively.			
(Lin et al., 2011)	**Classification**	**Content**	**User Study**
Description: An interactive touch-based system with AR to learn fish conservation **Technologies**: Special technology arrangement, ARToolkit, Virtoolkit, 3DSMax, Media Studio Pro 8, PS, AI, Avatar Design, Avatar Video Design, Touch Surface, Monitor **Authored: No**	**Tracking**: Marker **Display:** Video **Dev. Category**: Spatial **Collaborative: No** **Competitive: No** **Individual**: Yes	The game is a virtual pool with fishes. The game provides information about the fishes and their care. **Subject Matter**: Fish Care	**Sample size: -** **Time of Treatment: -** **Time of Session: -**
Method: Participants used the system and filled-out a questionnaire about its usability.			
Comments and recommendations: This approach does not include a teacher authored content or feedback from the professor. It does not mention an evaluation on the users performance or knowledge after the educational experience			
(Juan et al., 2011)	**Classification**	**Content**	**User Study**
Description: This paper presents AR Greenet and BasicGreenet. This row explains the game ARGreenet which is a game for teaching recyclyng. Authors conduct a comparison with another game namely, BasicGreenet and they conclude after the evaluation that ARGreenet and BasicGreenet were accepted but	**Tracking**: Marker **Display:** Video **Dev. Category**: Not Clear **Collaborative: No**	The game proposes a set of levels and information about recyclyng. The player has to take the rubbish into the right containers. Is that simple. **Subject Matter**: Recyclyng	**Sample size: 38** **Time of Treatment:** Short sessions **Time of Session:** Short

that ARGreenet was perceived as more fun than the non-AR one. **Technologies**: Visual C++, ARToolkit, Nokia Mobile Phone with Symbian. **Authored: No**	**Competitive: No** **Individual**: Yes		
Method: Quantitative data was collected on a set of two groups of 19 students with a median age of 10. They used the games and answered to questionnaires pre and posttest. They were also assessed on a small test			
Results: Both games are very positively accepted by users - There is not any statistical evidence that ARGreenet is perceived to be different from BasicGreenet - Our results suggest that participants experienced a moderately high sense of presence using ARGreenet - the games did influence the knowledge of participants			
Comments and recommendations: This study is a one-time experience. I think it's not likely that these results are somewhat conclusive. The change in the behavior should be addressed by one experience? Also, the content of the recycling experience can be changed and the professor has no role in it.			
(Campos & Pessanha, 2011)	**Classification**	**Content**	**User Study**
Description: An Augmented Reality Tangible Interface for Kindergarten **Technologies**:- **Authored:** No	**Tracking**: Marker **Display:** Video **Dev. Category**: Spatial **Collaborative: Yes** **Competitive: No** **Individual**: No	The game contains a lottery game where children can see animations of animals **Subject Matter**: Animals	**Sample size:** N/A **Time of Treatment:** N/A **Time of Session:** N/A
Method: Qualitative Design-based research. Students used the system and then they were interviewed.			
Comments and recommendations:			
(LogicalChoiceTech, 2011a)	**Classification**	**Content**	**User Study**
Description: These are two applications. A GBL AR game for teaching numbers, colors and measurements. It has some non-AR features too. And A GBL AR game for teaching reading **Technologies**: **Authored:** No	**Tracking**: Image **Display:** Video **Dev. Category**: Mobile **Collaborative: No** **Competitive: No** **Individual**: Yes	The game has AR cards that come alive. With them the kid can form phrases and the cards enact some kind of animation. This is meant to learn letters. The content includes animations, videos, and information about animals. **Subject Matter**: Animals, Reading	**Sample size: -** **Time of Treatment: -** **Time of Session: -** **Method: -**
Comments and recommendations: Just a video, not paper			
(Ternier et al., 2012)	**Classification**	**Content**	**User Study**
Description: game that simulates a hostage situation. Players must play a role-playing game to solve the case. There is also an AR location-based game authored with ARLearn. The game was meant to be played in a field trip to Florence. The game shows some questions authored by the teacher. Students have to answer the question by recording an audio or taking a	**Tracking**: Geo **Display:** GUI-Map **Dev. Category**: Mobile **Collaborative: No** **Competitive: No** **Individual**: **Yes**	The game depicts a simulation of a hostage situation. It has information accessible to inquiry and science thinking. **Subject Matter**: Cultural Heritage	**Sample size: 8** **Time of Treatment:** One Session **Time of Session:** One afternoon

picture **Technologies**: ARLearn **Authored:** Yes			
Method: Interviews after the experience. Qualitative result			
Results. Teacher liked the approach. It was somewhat difficult to create the questions. It was somewhat difficult to monitor the students. Students had no problem with the teacher tracking their progress.			
Comments and recommendations: Although this was not the case, a good option should be the BYOD Bring your Own Device strategy, where attended use their own device It is recommended to create a demo run to let user get used to the device or game. The UNHCR situation game is intended to be one-shot game and there seems to not be the participation of a trainer. This is one of the few applications that are aimed to author games and AR for learning. But, they are only aiming to location-based games			
(PBSKids, 2012)	**Classification**	**Content**	**User Study**
Description: An application for learning addition and subtraction **Technologies**: **Authored: No**	**Tracking**: Marker **Display:** Video **Dev. Category**: Mobile **Collaborative: No** **Competitive: No** **Individual**: Yes	It features several early childhood mathematical exercises. The user has to use the markers and his tablet to resolve operations. **Subject Matter**: Addition and Subtraction	**Sample size: -** **Time of Treatment: -** **Time of Session: -** **Method: -**
Comments and recommendations: It's an app not a paper			
(Barreira et al., 2012)	**Classification**	**Content**	**User Study**
Description: A game useful for teaching English language words by matching words and objects **Technologies**: OpenVRML, ARToolkit, USB Camera, OpenCV **Authored:** Yes	**Tracking**: Marker **Display:** Video **Dev. Category**: Spatial **Collaborative: No** **Competitive: No** **Individual**: No	The game presents content related with the learning of words for children. The markers show graphics and animations of the words. **Subject Matter**: Words	**Sample size: 26** **Time of Treatment:** One Session **Time of Session:** 90 minutes
Method: A 45 minutes class was given to the 26 students. Then they were separated into two classes of 13 students each. One group was the control group and the other the experimental. A diagnostic and a formative test were assessed to observe the children progress.			
Comments and recommendations: This is an interesting experience an effect size can be calculated. Nonetheless the participation of the teacher seems to be secondary. Also, the game's content is not editable.			
(Yamabe & Nakajima, 2013)	**Classification**	**Content**	**User Study**
Description: This work has three games: A game which uses a projector and camera to project over the real Go board hints to help the user train on the game A playful training system for learning to play Poker, it uses the heart rate of the players. A playful training system for learning calligraphy. The system	**Tracking**: Image **Display:** Projective **Dev. Category**: Spatial **Collaborative: No** **Competitive: Yes** **Individual**: Yes	1) The game is a virtual advisor. It recognizes the Go board and gives the player hints. There is a training mode also. 2) The game is a training space for playing poker. It shows hints for the gameplay based on the cards shown and the heartbeat of the players. 3) This system helps a person that is learning calligraphy in Japanese and Chinese characters. There is not content but it gives feedback regarding the posture of the writer and the right form to write a character. **Subject Matter**: Go, Poker, Calligraphy	**Sample size: 18/8/6** **Time of Treatment:** One Session **Time of Session:** **-**

gives feedback of the user's calligraphy **Technologies**: Projector, PC-Camera, Proprietary expert System, OpenCV, Flash, Go board, Bluetooth Heart rate sensors, RFID tags. **Authored:** No			
Method: Volunteers used the system. They were divided in two groups. One used the AR mode, the PC mode and then traditional learning. The other group started with the PC mode, the AR mode and then traditional learning. They were assessed with the IMI for motivation, pressure, competence and value			
Comments and recommendations: Authors developed a framework for constructing playful training with AR projective system for reality oriented contexts. It seems that they used the framework and previous definitions of the architecture of the system following the guidelines of the framework. Both architecture and framework are shown in the paper. Playful Training with AR projective games. This is a new concept based on AR it is Reality oriented augmentation. Also, the materials of the experiences are still expensive; nonetheless this could become a tendency for the future because of its non-intrusive feedback feature.			
(Bressler & Bodzin, 2013)	**Classification**	**Content**	**User Study**
Description: A vision-based AR game played inside the school environment with Quick Response codes. **Technologies**: ARIS. QR Codes **Authored:** Yes	**Tracking**: Image QR Codes **Display:** Video **Dev. Category**: Mobile **Collaborative: Yes** **Competitive: No** **Individual**: No	This is a Science Inquiry game its content has a "crime" scene that students have to solve. **Subject Matter**: Science	**Sample size: -** **Time of Treatment:** Two Weeks One Session per group **Time of Session:** One afternoon
Method: Each group played the game collaboratively during after school hours. They were assessed with questionnaires on flow experiences, gender influence, interest in science and gaming attitude			
Results: Gaming attitude was a significant predictor of flow experience; gender and interest in science were not important predictors. The interdependent nature of gameplay seemed to increase social flow. This study suggests that playing narrative-driven, inquiry-based science games can increase science interest for both genders			
Comments and recommendations: It is hard to think of this as an AR game. Although it is a place-based experience it is inly based on a QR code scan.			
(Stefan & Moldoveanu, 2013)	**Classification**	**Content**	**User Study**
Description: A game for teaching 3D modeling. **Technologies**: Junaio, Metaio Creator, Metaio SDK **Authored:** No	**Tracking**: Image QR Codes **Display:** Video **Dev. Category**: Mobile **Collaborative: No** **Competitive: No** **Individual**: No	**Subject Matter**: Science	**Sample size: -** **Time of Treatment:** - **Time of Session:** - **Method: -**
Comments and recommendations: It is only a concept, but the paper give some interesting insight into GBL + AR			
(Johnson & Sun, 2013)	**Classification**	**Content**	**User Study**
	Tracking: Image	The game shows projected images of the human anatomy	**Sample size: 50**

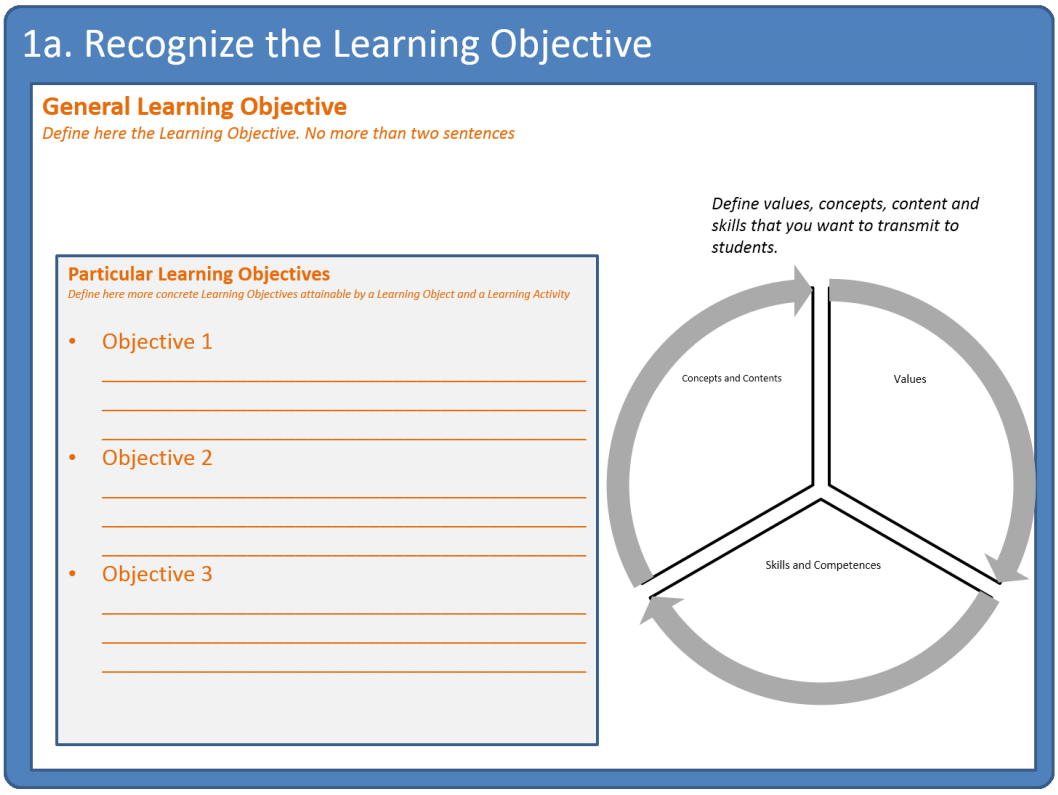
Description: A system which displays a projection of anatomy over the body of a person **Technologies**: Kinect, Projector **Authored:** No	**Display:** Projective **Dev. Category**: Spatial **Collaborative: No** **Competitive: No** **Individual**: Yes	**Subject Matter**: Anatomy	**Time of Treatment: -** **Time of Session: -**
Results: Teachers agreed the system could be effective. Students seemed to be more interested in anatomy. Incorrect anatomical identification were reduced by those using the system			
Comments and recommendations: This is a very short article (2 pages) although the study has an evaluation phase; it is hard to say if it is statistically valid. Also, the application is low-level engineered and they do not mention the teachers participation			
(Y.-S. Wang et al., 2013)	**Classification**	**Content**	**User Study**
Description: A marker-based GBL system with a character that explains the library coding system **Technologies**: ARToolkit with Visual C++ 6.0 **Authored: No**	**Tracking**: Marker **Display:** Video **Dev. Category**: Spatial **Collaborative: No** **Competitive: No** **Individual**: Yes	The game offers a set of contents and information in the form of audio visual materials through an AR agent. The content is intended for library instruction **Subject Matter**: Library Instruction	**Sample size:** 116, 61 males 55 females **Time of Treatment:** 1 session **Time of Session:** 2 hours + 1 hour explaining the system
Method: The group was divided into two groups: the experimental and the control one. They were assessed to measure performance with a pre and a post test. Also, they were assessed to know their learning style.			
Results: The use of the GARLIS and the other instructional method did not differ in terms of performance. GARLIS can be used when there is lack of personal to conduct library instruction. the system is more helpful in promoting the learning performance of learners with the field- dependent cognitive style than the conventional librarian			
Comments and recommendations: The study does not report significant differences between the use of the system and traditional instruction. Also it could be interesting to observe the cost vs. effectiveness of the system to analyze if it is worthy. The teacher participation was null.			
(Maiorescu & Sabou, 2013)	**Classification**	**Content**	**User Study**
Description: A games based heritage learning. A proposal for the Romanian heritage fortress from alba iulia. **Technologies**: GPS, Mobile device **Authored: Not clear**	**Tracking**: Marker **Display:** Video **Dev. Category**: Mobile **Collaborative: No** **Competitive: Not Clear** **Individual**: Yes	The game seems to be all-content. The AR interaction seems to be limited to the scan of a marker, but it is not clear. The content displays information to tourists about the castle they are in. **Subject Matter:** Cultural Heritage	**Sample size: -** **Time of Treatment: -** **Time of Session: -** **Method: -**
Comments and recommendations: The paper does not report full details on this experience. It says an "AR device" scans a marker but it does not show enough information or examples to understand that. Not to mention it does not have any evaluation at all. Also, it seems that the device for GPS location is different to the AR device. The paper is not clear.			
(Ferrer et al., 2013)	**Classification**	**Content**	**User Study**
	Tracking: Marker	The "game" (it is more of a simulation) provides the student with the	**Sample size:** 36

Description: An application for teaching the architectural configuration of a house to get optimal temperature from the sun. **Technologies**: Phone: HTC Desire HD, AR Qualcomm, Unity3D **Authored: No**	**Display:** Video **Dev. Category**: Spatial **Collaborative: No** **Competitive: No** **Individual**: Yes	calculations about the temperature in the house. The student can play around with the marker and the GUI options to configure the house according to the position of the sun. This is assumed to lead to learning about the architectural issues on temperature of a building. **Subject Matter**: PSE - Passive Solar Energy	**Time of Treatment**: 2 sessions 24 hr. apart **Time of Session:** 30 minutes
Method: The participants were interviewed and trained in the interface of the system. They used the system directed by a person in charge. They were asked to complete some tasks In day 2, they filled a questionnaire on performance and motivation they ran an optimization task into the system and then they were post-interviewed. There was an ANOVA and a set of statistically validated quantitative analyses.			
Results: Usability: A one marker design with a touchscreen interface may have a usability advantages over a touchscreen-tangible hybrid design for AR serious games. • Learning: In some cases, a one-marker AR design may have increased learning benefits over a multi-marker design • Motivation: Despite decreased usability, AR serious games can enhance motivation to learn over desktop interfaces.			
Comments and recommendations: This is not a game properly spoken. It is more like a simulation. They used computer science students maybe because that way the test could be done with people with no clue about architecture.			
(Martinez et al., 2013)	**Classification**	**Content**	**User Study**
Description: A mobile game with AR for learning animals interacting with a virtual l zoo over a marker **Technologies**: Unty3D, Cinema4D, Javascript, XML **Authored:** No	**Tracking**: Marker **Display:** Video **Dev. Category**: Mobile **Collaborative: No** **Competitive: No** **Individual**: Yes	The game portraits a zoo for the learning of animals **Subject Matter**: Animals	**Sample size:** 5 **Time of Treatment: -** **Time of Session: -** **Method:** A usability test
Comments and recommendations: This is just a standalone experience; it only reports a simple test on usability.			
(Gomes et al., 2014)	**Classification**	**Content**	**User Study**
Description: A simple game-like activity using AR to leverage learning on sound related concepts. **Technologies**: **Authored: No**	**Tracking**: Marker **Display:** Video **Dev. Category**: Spatial **Collaborative: Not Clear** **Competitive: No** **Individual**: Yes	This is a simple game that uses markers and marker-based interaction to teach about sound concepts like volume and pitch. The tool is very interactive and lets children understand and explore the content by themselves. Authors conduct an auto-report test of usability. **Subject Matter**:	**Sample size: 6** **Time of Treatment:** Short **Time of Session:** Short **Method:**
Comments and recommendations: Some children were special needs children			
(H. Tobar-Muñoz, Baldiris, et al., 2014)	**Classification**	**Content**	**User Study**
Description: A game with AR meant to be used for learning basic logical operations of ordering and pairing. **Technologies**: Unity3D, NyARToolkit **Authored: No**	**Tracking**: Marker **Display:** Video **Dev. Category**: Spatial **Collaborative: No** **Competitive: No**	Gremlings in my Mirror's levels are designed in such a way that the students must pair, or order a series of "gremlings" depending on the goals of each level. The game makes use of the webcam and it is manipulated through a set of AR markers. **Subject Matter**: Mathematics	**Sample size: 20** **Time of Treatment: Short** **Time of Session:** Short **Method: Design-Based Research**

	Individual: Yes		
Comments and recommendations: Some children were special needs children			
(Hodhod et al., 2014)	**Classification**	**Content**	**User Study**
Description: A game meant to be used for learning problem-solving skills. **Technologies**: Mobile Phone **Authored: No**	**Tracking**: Marker **Display:** Video **Dev. Category**: Mobile **Collaborative: No** **Competitive: No** **Individual**: Yes	The game is about a race of alien (the Zeomons) s in a planet that is being invaded. The game environment is presented in a sheet of augmented paper and the aliens present some tasks. The game is innovative because it used the concept of "Believable Pedagogical **Subject Matter**: Mathematics	**Sample size: N/A** **Time of Treatment: N/A** **Time of Session: N/A** **Method: N/A**
Comments and recommendations:			
(C.-H. Chen et al., 2015)	**Classification**	**Content**	**User Study**
Description: A game using AR to learn about the food chain **Technologies**: Visual C++, ARToolkit, 3DS max, Adobe Illustrator **Authored: No**	**Tracking**: Marker **Display:** Video **Dev. Category**: Spatial **Collaborative: No** **Competitive: No** **Individual**: Yes	Authors propose a game with two pages in a self-made book. Also they use markers to represent the actions of the players in the game. Players have to put the markers in the appropriate places in the board in order to play. The objectives of the game are NOT FLASH-CARD-ish... they actually made a game where the objective is not a simple solution, but where the player has to think about the game content. **Subject Matter**: Science	**Sample size:** 10 **Time of Treatment: -** **Time of Session: -**
Method: Simple Tests on usability and motivation			
Comments and recommendations: This is one great example very related to what we are looking for. Although its results are preliminary			
(Furió et al., 2015)	**Classification**	**Content**	**User Study**
Description: A game for learning the cycle of water. The application uses AR over a marker-based platform. Authors created a plastic support to ease the handling of the mobile device. **Technologies**: Iphone 3GS with IOS 4.3 Xcode 4 IDE, Iphone SDK, ARToolkitPlus, SIO2 1.4, OpenGLES 1.1, Blender **Authored: No**	**Tracking**: Marker **Display:** Video **Dev. Category**: Mobile **Collaborative: No** **Competitive: No** **Individual**: Yes	Students are presented with the AR app and a set of markers around a table in the classroom. The game has 7 mini-games. Each one explains an aspect of the Cycle of water. A marker with a drop of water represents a main character which helps students in the game. The game also includes non-AR games which include contents of the cycle of water topic. **Subject Matter**:	**Sample size:** **Time of Treatment:** One Session **Time of Session:** Short
Method: This was a quantitative study comparing the application of the AR game and a traditional strategy. They also made a satisfaction and motivation study. They conducted an ANOVA analysis to analyze other factors like gender and school-grade.			
Results: Students do not show a difference in performance and learning gains between the students who used the AR game and students who did not. However, in the satisfaction and motivation study, students who used the game showed more motivated and satisfied than children who did not.			
Comments and recommendations: This study is much related to our study. In this study the game is used by students in a naturalistic environment: Their classroom. It is interesting how they do not find a difference between the experimental and control groups. However, it is noteworthy that the test they used was very limited as it had only 6 questions with multiple answers.			

APPENDIX C. TEMPLATES OF THE FRAMEWORK FOR DEFINING THE ARGBL GAME IDEA

Here the templates that the method Co-CreARGBL proposed for defining the game concept are presented in a bigger format.



1b. Empathize with the student

Aesthetics

- *Here we define what the student is looking for. Think how to use his or her desires for learning in the AR game. Some examples:*
  - *Discover*
  - *Listen to a Story*
  - *Collect*

Player

- *Who is the student? Characterize the student's persona.*

Context

- *What is the context of the student? The context's is the student's environment, his or her language and their social background.*

Dynamics

- What is the summary of the experience that the game will bring to the students?

2a. Brainstorming

In this frame of work we will use the Post-its. Yellow represent game ideas and blue represent AR aspects. Some considerations are shown here. Paste the post-it according to the element that it relates to.

Environment
(Defines the limits and the space of the game)
Board, Maps, Field, Room

Components
(Objects that the players use)
Pieces, Characters, Tools, Symbols, Objects

Conditions
What happens when the student plays?
Hos to win the game?
When the game is lost?
When the game is won?

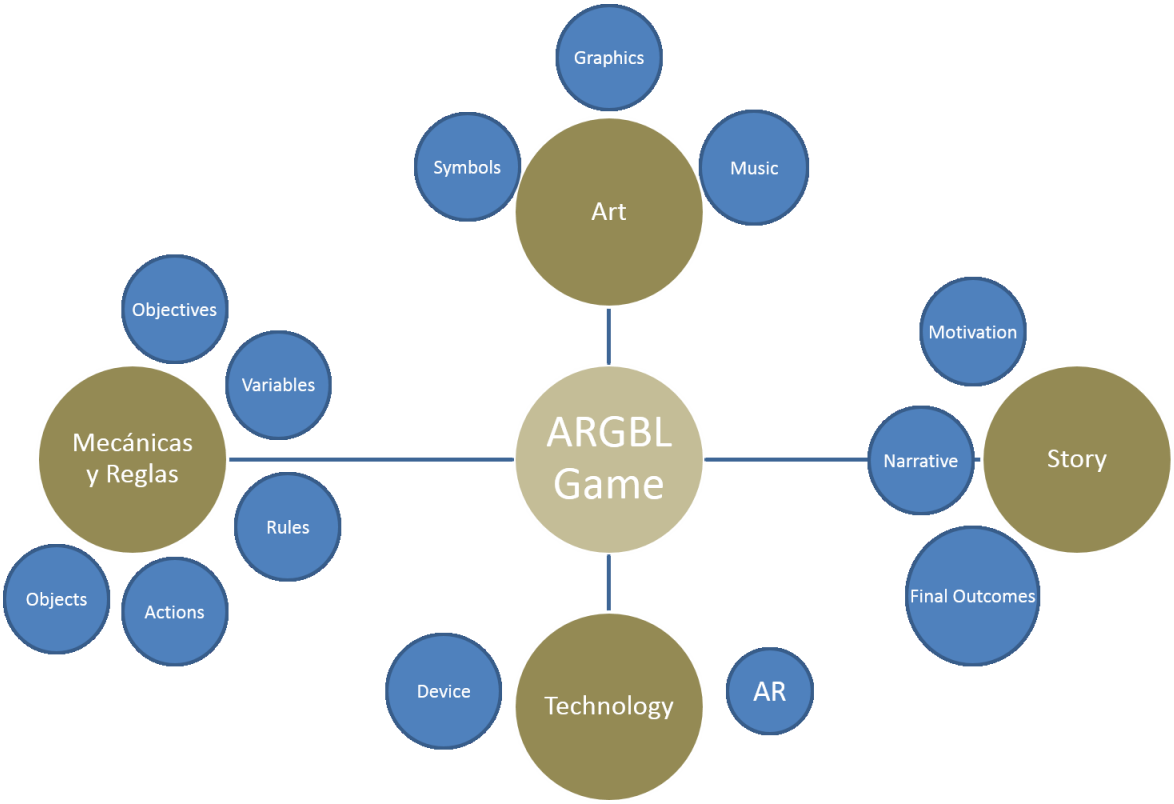
Rules
What are the limits, obstacles, roles, information, variables, goals, constraints the gam has?

Augmented Reality
What is Augmented?
Why is it Augmented?
When is it Augmented?
What is the virtual information?
What is invisible and turns into visible with AR?

Interface
What does the player see in the game?
How does the player use the device?
What does the student(s) see?

2b. Decompose the Ideas and form a game

A game can be divided in 4 aspects
Art
Mechanics (the functions of the game)
Technology that it uses
Story
We will use the Post-its used in the previous part and we will move them to the parts of the game in the next part. We will Select those that we like the most and propose a game idea with them.



3a. Game Concept

Here we define the Game idea. We will write the game idea as if it is already created.
Answer:
¿What is the game? ¿How is it played? ¿What is the goal? ¿What are the rules? ¿How it achieves the learning goal? ¿How it makes use of AR?

3b. Discuss the Idea and Refine

- The game models the learning object?
- The game allows the student to take decisions and live their own experience?
- The game allows the student to use the rules to reach the goals?
- The game allows the student to control freely their game components?
- Does the player take interesting decisions?
- Augmented Reality shows virtual and important information?
- The game shows information when the students asks for it?
- Is the game boring?

3a. Game Concept (refined)

Here we define the Game idea. We will write the game idea as if it is already created.
Answer:
¿What is the game? ¿How is it played? ¿What is the goal? ¿What are the rules? ¿How it achieves the learning goal? ¿How it makes use of AR?

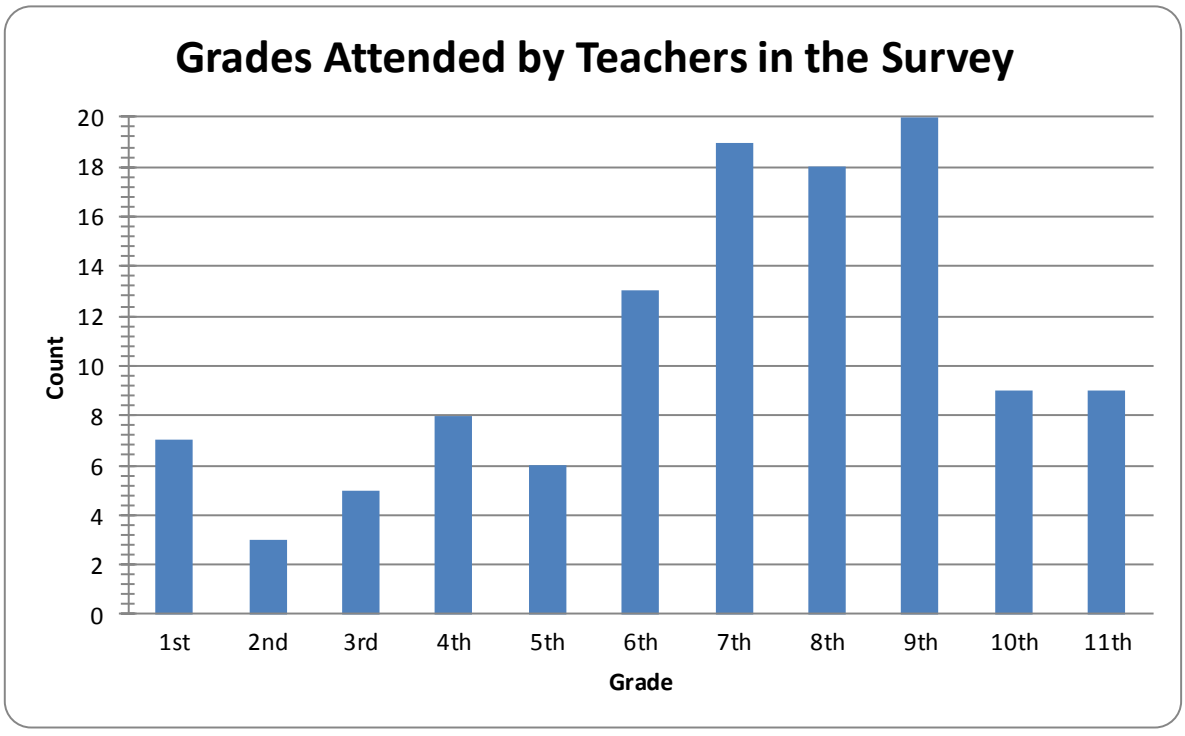
3d. Game Information

- Name
- Learning Objective
- Game Objective
- Conditions:
  - Victory
  - Defeat
  - End
- Main Mechanics

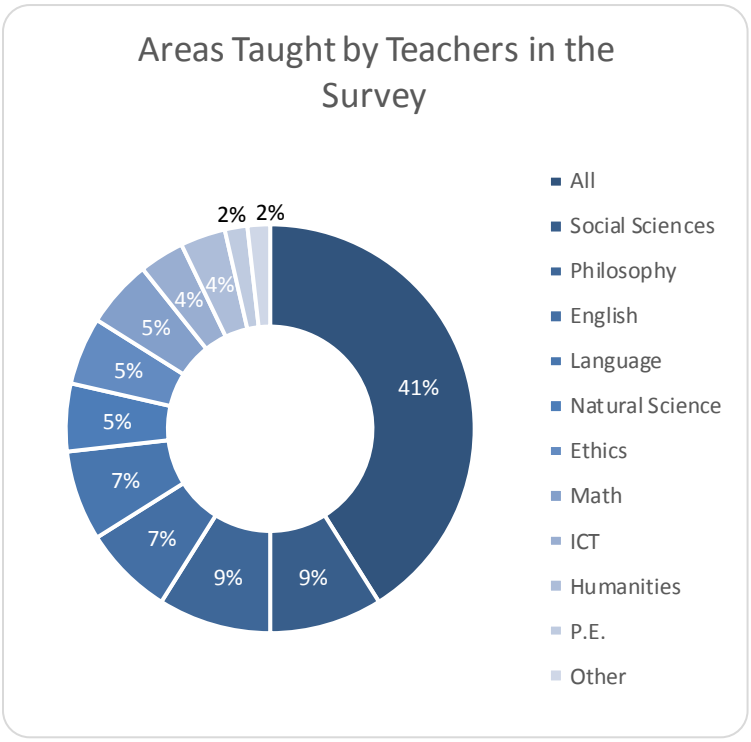
APPENDIX D. OTHER RESULTS OF THE PRE-SURVEY CONDUCTED ON TEACHERS DURING THE TRAINING

Here we show other results of the survey conducted on the teachers who participated in the training stage during the application of the method to the case studies.

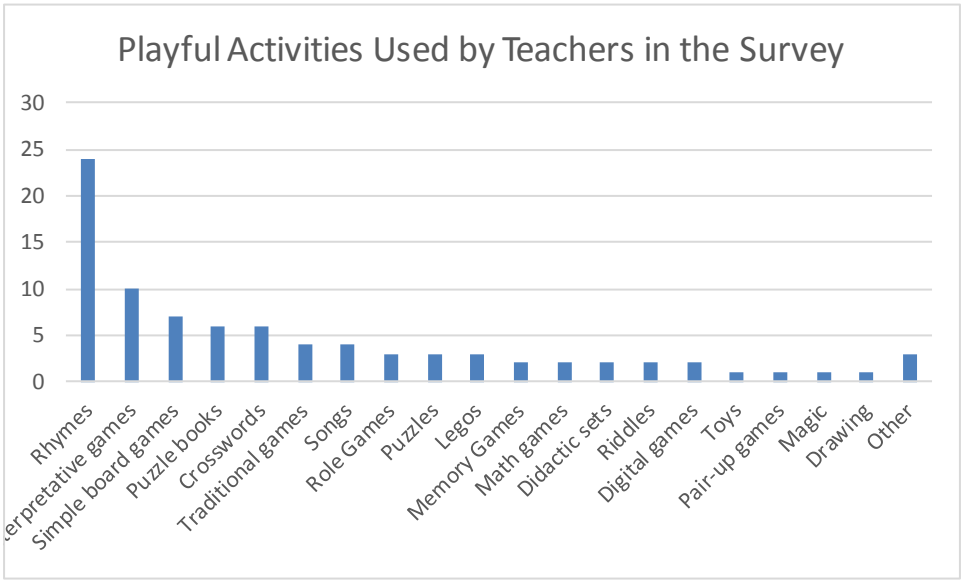
The following figure shows the distribution of grades attended by the teachers. In the figure it can be seen how most teachers taught at the middle school level.



Teachers reported teaching on the areas depicted by the following figure. It is noticeable how many of the areas mentioned by the Teachers include "All" of the subjects. This is because in Colombian schools there is a tradition in which just one Teacher teaches to a class in elementary school.



In the survey Teachers reports having used playful activities during their classes. They also gave some examples of the playful activities. The following figure shows the classification of the activities mentioned by the Teachers. The term used on the survey was "actividades lúdicas" meaning that Teachers were asked to report on any learning activity in which students played in any way. The classification shows that most Teachers used nursery rhymes and interpretative games during their classes. This means that while some Teachers mention structured games such as Simple Board Games, most of them mention playful activities that involve singing songs and playing socially in rhymes and chants.



APPENDIX E. INSTRUMENTS USED TO EVALUATE MOTIVATION DURING THE VALIDATION OF THE METHOD

The following is the instrument used to evaluate the motivation on the student in the two cases of the validation of the Co-CreARGBL method (Chapter 6). The instrument asks the student to compare the motivation with the game (labeled "El Juego" in the instrument) and the traditional instrument such as the Info Sheet.

Hi! Now that you have participated in the experience [Name], Could you answer some questions? Answer however you want, we only want to know how you felt.

Enclose in a circle the smiley which you identify the most with. For example if you enjoyed very much mark  A lot but if you enjoyed a little mark  A little

Name: _____ Age: _____ Grade _____

Interest/Enjoyment			
1	I enjoyed the activity with the…	Info Sheet	 Not at all A little Kinda Some A lot
		Game	 Not at all A little Kinda Some A lot
2	It was fun, the activity with the…	Info Sheet	 Not at all A little Kinda Some A lot
		Game	 Not at all A little Kinda Some A lot
3	It was boring the activity with the…	Info Sheet	 A lot Some Kinda A little Not at all
		Game	 A lot Some Kinda A little Not at all
4	It did not kept my attention	Info Sheet	 A lot Some Kinda A little Not at all
		Game	 A lot Some Kinda A little Not at all
5	It is interesting	Info Sheet	 Not at all A little Kinda Some A lot

		Game	
6	It is enjoyable	Info Sheet	
		Game	
7	When in the activity you were thinking how much you liked the…	Info Sheet	
		Game	
Effort/Importance			
8	I place my efforts in the activity with the…	Info Sheet	
		Game	
9	I did not try to do well the activity with the…	Info Sheet	
		Game	
10	I strived fiercely in the activity with the …	Info Sheet	
		Game	

11	It was important to me to work with the…	Info Sheet	
		Game	
12	I did not place a lot of energy to the…	Info Sheet	
		Game	
Value/Usefulness			
13	I think it could be valuable for me the…	Info Sheet	
		Game	
14	To learn about [subject] it is very good the…	Info Sheet	
		Game	
15	I think it is important because it helps me to [subject component]	Info Sheet	
		Game	
16	Because it is useful, I'd like to use again the…	Info Sheet	

		Game	
17	It helps me to value more the [subject]	Info Sheet	
		Game	
18	It is good for me the…	Info Sheet	
		Game	
19	It is important to me the…	Info Sheet	
		Game	

APPENDIX F. LEARNING GAINS EVALUATION INSTRUMENTS USED DURING THE VALIDATION OF THE METHOD

The following are the evaluation instruments used when Teachers conducted the assessment of the Learning Gains on the students.

Team A

Here, the instrument is translated from the original Spanish.

During this stage we will perform the assessment on the Learning Gains of students who participated on the game "Una Aventura por el Cauca"

For this you will have to check the videos taken during the evaluation of the students. These were done during two phases: Before the game (diagnostic evaluation) and after the game (formative evaluation).

This form asks you to evaluate the performance of the students using a scale from 1 to 10.

To perform the assessment, please evaluate from 1 to 10 according to the themes that the interviewer in the video asks to the students.

Consider the following rubric:

Score	Criteria
10	The student knows about the theme and relates truthful aspects of it, without misconceptions, assumptions or extrapolations. The student is sure of his or her answer.
9	
8	
7	The student knows about the theme, but seems to not be sure of his or her answer or his or her answer is vague, not clear or incorrect. or The student answers only from their experiences and not from the educational content.
6	
5	The student knows some aspects of the theme, but his or her answers oscillate between misconceptions, assumptions and ignorance.
4	
3	The student answers but with incorrect answers and he or she does not seem sure of their answers.

2	
1	
0	The student answers that he or she does not know about the theme.

Other questions in the form ask about the general level of sureness of the student. You must answer: very low, low, medium, high or very high.

Student Evaluation Form

Group Code: _____

Name of the Student: _____

Diagnostic Evaluation

Theme	**Score**
General	
Tourism	
Festivities	
Hydrology	
Archaeology	
Economy	

Comments

Is the student sure of his or her answers?

_____

Formative Evaluation

Theme	**Score**
General	
Tourism	
Festivities	
Hydrology	
Archaeology	
Economy	

Comments

Is the student sure of his or her answers?

_____

The answers of the students are according to what was seen in the ARGBL activity? *(Yes, No, More or Less, Not Clear)*

____

Does the student reflect Learning Gains after the activity? (Yes, No, More or Less, Not Clear)

_____

Team B

The following are the questions asked by the Teacher during the diagnostic dialogue with students. *The questions here are translated from the original Spanish. The questions are an excerpt of a broader document explaining the evaluation activity wrote by teachers. That document can be found in the accompanying website.*

1. *Who are you [as a being]?*
2. *Who are we [as a community]?}*
3. *What is the meaning of the family?*
4. *What is the family?*
5. *What is the maize?*
6. *Why is the maize important?*
7. *Have you ever participated in the cultivation of maize?*
8. *How is the maize cultivated?*
9. *Why is the Nasa Calendar important?*
10. *What are the rituals in the Nasa Calendar?*
11. *Who has participated in the Shakelu ritual?*
12. *What did you observe in the seeds rituals?*
13. *Why is this ritual important to the families?*

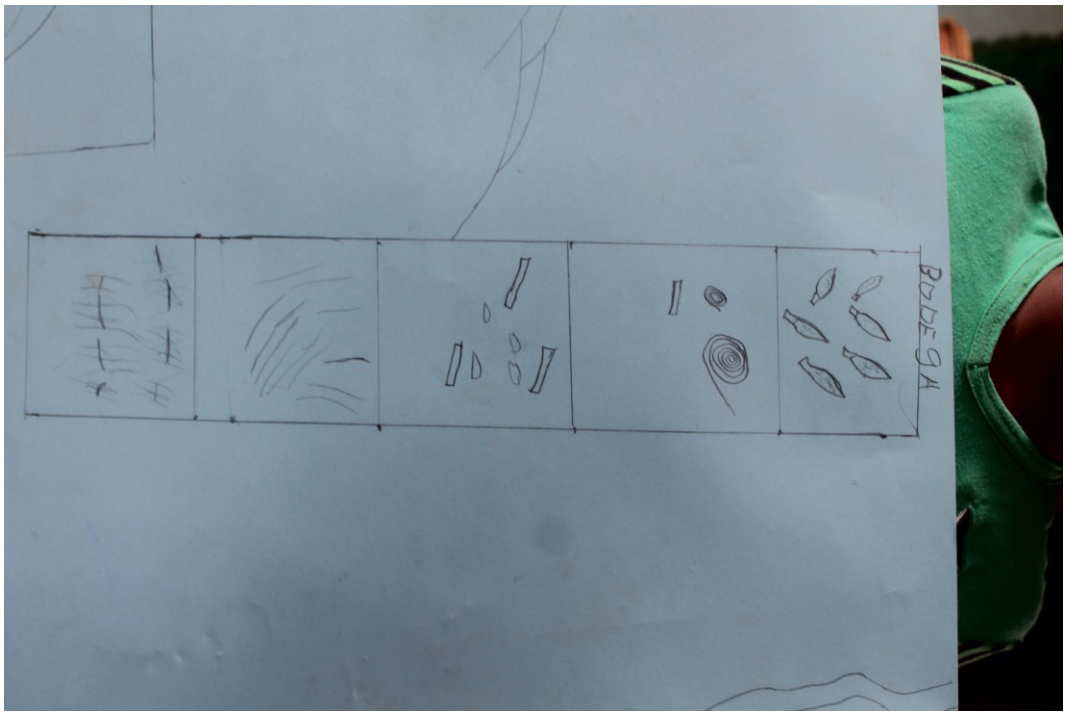
After the activity was conducted the Teacher proposed the evaluation activity which consisted in the students drawing freely what they had learned regarding the activity with the ARGBL game. Then, they were asked to present the drawing with a short presentation on what they felt they had learned during the activity.

The following are some photographs of the drawing made by students, taken during their presentation with a short explanation. Notice how some students represented concepts present in the game.

This student's drawing shows the main female character and her work in the mountain. It also shows the *Jigras* and at the right it shows the storage.

This student drew the main male character working in the mountain.

This student represented the elements in the barter such as the maize, *cabuya,* and wool. The representation is directly taken from the game's board.



Other students just drew aspects of the nature, perhaps as they were present in the game's art and the game's board background.

APPENDIX G. SEMI-STRUCTURED INTERVIEWS CONDUCTED ON TEACHERS

In this Appendix, the questions used during each of the interviews are shown. Numerals show the main questions and literals show the sub-questions that could arose based on their corresponding question.

INTERVIEW I (MADE AT THE BEGINNING OF THE PROCESS)

1. Evaluate from 1 to 10 the results obtained from the process. Explain yourself.
2. What were the positive aspects of this process?
3. What were the negative aspects of this process?
4. Do you feel the time allotted to the process was an obstacle for the success of it?
5. Do you think there was plenty of time to conclude the process satisfactorily?
6. Do you feel you had support from your institution?
7. Would you share the product with other teachers? ¿Why?
8. Do you consider you have appropriated the product?
9. Would you do it again?

INTERVIEW II (MADE DURING THE PROCESS AFTER THE DESIGN ACTIVITY)

1. From our experience up until now, can you mention (in your own words):
    a. Uses and advantages of ARGBL for learning?
    b. Design Principles
2. How do you think those uses, advantages, and principles have affected:
    a. The design of the artifact
    b. Your understanding of teaching
3. How do you think the Specification and Analysis Activities were conducted during the project? Can you mention some examples?
4. The process we are conducting is a Do-Design process centered around the collaborative work:
    a. What have you done during this process?
    b. Do you think it has advantages? Which?
    c. Do you think it has disadvantages? Which?
    d. How do you think your performance on the collaborative process has been? Do you think you should improve it? How? Why?
    e. Imagine this process involved only teachers without designers. How would such a process be comparing with ours?
    f. Imagine this process involved only designers without teachers. How would such a process be comparing with ours?

INTERVIEW III (MADE AFTER THE PROCESS FINISHED)

1. From our experience up until now, Can you tell me: In what consists the Iterative Design Stage of a game with AR for learning?
2. From our experience up until now, Can you tell me: In what consists the Evaluation Stage of a game with AR for learning?
3. Through your experience on this process, Do you think you comprehend the stages needed to create the ARGBL game?
4. (*If the teacher answers yes to the previous question*)Suppose new teachers and designers join the team for creating a new game. ¿What step-by-step process would you follow?
5. Do your think this collaborative process has been useful for you and your school? Why?

Satisfaction Questions

6. Evaluate from 1 to 10 your satisfaction with the process. Explain your answer.
7. What were the positive aspects of this experience?
8. What were the negative aspects of this experience?
9. Do you think the time was an obstacle to conduct this experience satisfactorily?
10. Given that were many months on the process, do you think there was enough time to conclude it satisfactorily?
11. Did you feel supported by your institution?
12. Would you share the game with other teachers? Why?
13. Do you think you have appropriated the product? Why?
14. Would you do it again?