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Developing and Assessing Augmented Reality Applications for Mathematics with Trainee Instructional Media Designers: An Exploratory Study on User Experience

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Abstract: Various interactive and innovative applications generated by Augmented Reality (AR) technology have given great potentials in different learning subjects and specifically in STEM (science, technology, engineering, and mathematics) education. Nevertheless, previous studies regarding AR integration inside classrooms have shown that as a valuable technology for students' motivation and participation alone cannot automatically lead to its successful use. This study focuses on teaching and learning mathematics by taking advantage of AR technology to visualize several problems and let users interact with its contents. In this perspective, the purpose of this study is to present an instructional approach by which competencies of seventy-eight (*n*=78) trainee instructional media designers with a successful and appropriate integration of AR technology inside classroom contexts using HP Reveal and Blippar. In favor of designing and assessing AR applications for mathematics, the instructional media designers have shown satisfactory performance and user experience. Specifically, all AR applications seemed that enable the representation of intuitive learning scenarios and increased greatly users' interactive experience, thus encouraging their achievements and outcomes. This study contributes to the most relevant practices of teaching and learning for mathematics with the integration of AR applications which are developed by trainee instructional media designers to support successfully the educational process with several examples to be visualized by merging physical ("target tracking") with digital features and objects.

Keywords: augmented reality, instructional design, user expectations, user experience, user experience assessment
Categories: H.5.2., K.3.1, K.3.2, L.3.0, L.3.6, L.3.8

1 Introduction

There is a broad agreement that STEM (science, technology, engineering, and mathematics) programs have been extended to many countries across the globe. Statistical data indicate that there will be an accelerated growth in the number of STEM programs over the next decade, particularly compared to any other profession [STEM Education data 2017]. Many tasks related to STEM are integrating into formal or informal instructional contexts, requiring a solid understanding of basic mathematics concepts that are mostly situated with new technological sources and devices related to engineering, computer programming, or topics from the formal to the natural sciences. Therefore, mathematics is regarded as one of the most important learning subjects in STEM programs.

In this modern society, there is an increasing number of students who want to learn essential mathematics in order to face several difficult challenges in their real life using almost all newly technologically advanced devices which can influence to a large extent the "status quo" of the world of tomorrow. For this reason, many studies [Bouta & Paraskeva, 2013; Ojose & Sexton 2009; Roy et al. 2017] have advocated about the significant role of mathematics in school-age contexts as an essential learning subject in which students should start to participate from early ages of compulsory (primary and secondary) school education. One of the most distinctive objectives in mathematics courses is that it can give several opportunities to all students who want to calculate cognitive thinking skills related to problem-solving and higher-order using properly numbers, arithmetic fractions and/or to understand geometric shapes or properties. Through mathematics instruction, they can contribute to the formation of certain attitudes and practical skills based on the development of some mental attributes [Roy et al. 2017]. This seems to be required for students to learn and correctly to use the strictly structured language of mathematics, cultivating positive mental attitudes which are regarded as essential in their real life, such as accuracy, clarity, and problem-solving [Tanujaya et al. 2017]. Consequently, students need to acquire a functional knowledge of mathematical content to make informed decisions as citizens who are informed and educated through quantitatively complex tasks in this contemporary society [Wilkins & Ma 2003].

In compulsory education, mathematics courses are regarded globally as significant learning subjects in school curriculums. Many times, students learn basic mathematical concepts and arithmetic functions that are combined with practices in an effort to understand how can become useful these courses for problem-solving tasks [Kelly 2006]. Several studies and educational researchers have already recognized that mathematical knowledge is an ongoing attempt of students to identify basic learning components which can use the components of such knowledge to solve real-life problems and promote long-term learning. For example, Butcher and Aleven [2008] have suggested that long-term learning can be supported by visual information such as diagrams and symbols. Additionally, other studies [Bouta & Paraskeva 2013; Edwards et al. 2017] have concluded that students need to involve higher-order thinking skills and interact with other learning materials in a problem-solving process so that they can also produce higher standardized test scores. On the one hand, this leads the students to struggle in understanding the way of using what they learned in mathematics courses, albeit on the other, the way to improve their learning performance is something that still remains challenging.

Digital media applications generated by Augmented (AR), Virtual Reality (VR) and Mixed Reality (MR) have begun to find their way into a multitude of areas related to teaching and learning. From an instructional-educational perspective is of great interest to mention that such technologies have several differences in regard to the common media formats like videos or hard copies, giving users the opportunity to experience combining digital and physical contents or materials [Dunleavy & Dede 2014]. A substantial body of literature [Hung et al. 2017; Laine et al. 2016] has presented great potential and advantages in different STEM learning subjects, like the manipulation and visualization of abstract, complex or digital-oriented content which can offer alternative ways of self-discovery and constructivist learning processes. More specifically, AR technology in STEM education has covered a wide range of formal science topics [Atwood-Blaine and Huffman 2017; Hsiao et al. 2013], technology [Chen et al. 2016; Hwang et al. 2016], computer programming [Kazanidis et al., 2018c] and engineering [Boga et al. 2018; Velosa et al. 2018], and mathematics [Bujak et al., 2013; Sommerauer & Müller, 2014]. Based on previous literature reviews [Akçayır, M. & Akçayır, G. 2017; Bacca et al. 2016; Pellas et al. 2018], the use of AR applications in compulsory education can become a potentially valuable medium for teaching and learning. In specific, students are engaged through interactive activities in order to gain knowledge, having positive perceptions and attitudes to achieve better learning performance and outcomes.

However, a great number of studies [Akçayır M. & Akçayır 2017; Bacca et al. 2014; Pellas et al. 2018] have shown that potentials or advantages of AR applications are not automatically linked to their appropriate use inside the classroom. Prior efforts [Nadobly, 2017; Pellas et al., 2018; Wu et al., 2013] have supported the opinion regarding the self-perceived professional competence and development of the instructor which can influence the successful integration of AR as an innovative technology to teach and learn different STEM subjects. Related works [Dunleavy et al. 2009; Pellas et al. 2018; Wu et al. 2013] have argued that despite the positive students' attitudes and perceptions using interactive AR applications in STEM courses, limited research demonstrated about instructional media designers' experience as users and the effectiveness of using such a technology to support the students' learning in mathematics. Considering this aspect, teachers and scholars face several challenges when they must choose the most appropriate educational technologies, tools and teaching strategies that can stimulate the students' attention to affect significantly their engagement and participation in mathematics [Radović et al. 2018]. Information and Technology (IT) skills, attitudes and experience of trainee instructors using AR technology to develop applications for educational purposes can also determine its appropriateness in various learning subjects. HP Reveal[1] and Blippar[2] are today considered as two valuable "tools" which can be utilized by trainee instructional media designers who are non-programmers or have little background in computer programming to create applications and media formats. Instructors can cultivate or increase further relevant IT skills and attitudes based on the experience gained from their own "creations" requiring specific training sessions and preparation programs. Thus, such programs and sessions are not so easily provided into everyday education. This may affect negatively not only the use of AR technology for educational purposes but also the professional development of instructional media designers. According to this rationale, it is imperative the need to be provided possible ways or approaches which enable (trainee) instructors to create and assess successfully those AR applications which can be the most appropriate for their teaching interventions.

To address the above challenge, this study investigates whether the combination of AR tools that are described earlier with specific design features and characteristics

[1] https://www.hpreveal.com
[2] https://www.blippar.com/

can support trainees to develop interactive applications which can assist students to understand better mathematical practices. This may foster the transfer of learning as outcomes of proposed solutions to several mathematical concepts which are visualized as AR applications. The present study seeks to answer the following research question: *Has the use of AR tools (Blippar and HP Reveal) a positive effect on trainee instructional media designers' expectations, perceptions and learning experience so as to develop, apply and assess their own AR applications for mathematics courses?*

The purpose of the present study is twofold: (a) to elaborate a rationale on how AR tools can support the development of trainee instructional media designers' problem-solving practices to create interactive applications for mathematics and (b) to summarize the findings related to the learning performance, perceptions/opinions and user experience of trainee instructional media designers using AR tools (Blippar and HP Reveal). For this reason, an exploratory study is conducted in terms of developing and assessing AR applications with a total of seventy-eight (*n*=78) trainee instructors who participated voluntarily in six training lectures.

This paper is arranged as follows: Section 2 presents the background and analysis of the related work carried out on the use of AR in STEM education and specifically in teaching and learning mathematics. The results from previous studies reassure the learners' improvement in their learning performance and engagement in several tasks. Section 3 entails the main teaching treatment's details, the research method with emphasis on the experimental setup and treatment offered with AR applications. Section 4 encompasses the results of this exploratory study that unveiled at the end of the described teaching intervention. Section 5 discusses the results of the current study, the statistical analysis, and the feedback on learning experience received by the trainee instructional media designers. Finally, Section 6 concludes with the main findings, implications for design and practice. Lastly, future studies that need to be done are also proposed.

2 Literature Review

2.1 Learning Mathematics

Mathematics is an indispensable learning subject of all curricula around the globe in K-12 education. Learning mathematics is a cognitively complex and demanding task. It requires a synthesis of cognitive thinking skills, such as problem-solving, logical and arithmetic reasoning that enables students to transfer their thinking solutions into workable plans and fractions to real-world problems [Kelly 2006]. Both studies that described curricular activities [Department for Education 2012; Roy et al. 2017] and research circles [Budinski & Milinkovic 2017; Dunphy et al. 2014] in the field of teaching mathematics have revealed some important learning objectives in regard to the needs that arise on what students should learn. Some of the most important is described in detail from the most technologically advanced countries making able students: (a) to understand routine problems and solve them with specific suggestions applying relationships between quantitative variables; (b) to manage how to use effectively their problem-solving strategies without only constructing an algebraic or geometric model but judging their own personal experiences; and (c) to check the correctness of their answers, regardless of the kind of problem they solve.

Besides the above learning objectives, serious consideration should be also taken to any possible difficulties which exist based on the relevant international literature. For example, Klein [2003] has emphasized to the description of relevant problems that students have when they are trying to apply their problem solution plans and when they are working on familiar problems. Greer [1997] has mentioned that students' inability to answer correctly those verbal problems of mathematics and cannot understand how are being associated with real-life problems. Thus, understanding a problem is related to the acquisition of knowledge by classifying cognitive classes into categories that can help students to propose solutions [Ojose, 2008]. Ojose and Sexton [2009] have compared students' thinking when solving problems with a "ladder" in which they can initially use a simplified approach and overtime trying to solve it using by visualizing or analyzing mathematical concepts optically. Although students can respond to verbal problems, their answers do not always agree with common sense. Particularly interesting are also the discussions in research circles about students' conceptual and cognitive difficulties in dealing with the process of creating fractions and arithmetic reasoning challenges posed by the use of specific mathematical concepts [Budinski & Milinkovic 2017; Dunphy et al. 2014]. Therefore, they try to understand superficially and only conceptually any problem by subdividing its sub-parts or by choosing to make an act that can be done directly in order to calculate and give their finals answers without returning to the text [Wurman & Wilson 2012].

To sum up, a major problem in mathematics courses primarily results from the cognitive complexity that many students face, while difficulties for the appropriate reasons of using innovative technologies is becoming as another problematic issue. Students need to participate in learning tasks to gain early experiences with mathematical concepts, even before learning the requisite mathematics concepts use in their real-life.

2.2 AR Technology to Support Mathematics Courses

The rapid advancement in hardware and software combined with the explosive utilization of mobile devices, such as smartphones and tablets to increase students' learning participation through hands-on tasks which can give answers to several problems that require solutions in practice. Something that is usually observed is the extensive use of such technologies inside lecture-based instructional approaches providing a more active learning. To be successfully achieved the integration of such technologies, AR continues still today to be as one of the most promising that can attract educators and scholars' attention. It gives various potential and opportunities for the creation of interactive applications which can be utilized by the majority of learning subjects and domains [Wu et al. 2013]. AR as a system or a visualization technique entails three main aspects: (a) a combination of the real and digital (virtual) environment; (b) real-time interaction; and (c) accurate 3D registration between digital and real objects. In essence, Azuma [1997] was the first who referred that *"AR supplements reality, rather than completely replacing it"* [p. 356]. Additionally, the human senses with additional information can be increased beyond what is provided by a natural environment. In this respect, AR technology and currently its use for the development of applications allow users to understand effectively abstract or complex concepts, which can also lead to improved learning outcomes at different educational domains [Cai et al. 2016; Laine et al. 2016].

As mentioned earlier, mobile devices and specifically smartphones have been provided as essential inside school-age contexts. This technology is called "mobile AR" and is considered one of the most promising is easily accessible due to the high penetration of mobile phones [Alakärppä et al. 2017]. This topic is also important that needs further to be investigated the educational potential of AR applications, as international reports and projects have admitted. For instance, International Data Corp (IDC) has reported that the total use on AR/VR products and services increased up to $9.1 billion in 2017. The same organization predicts that in nearly 2021, many companies and organizations will spend almost $160 billion, growing the ratio rate up to 113.2%. The 2016 Horizon Report has also mentioned that AR is a "soon-to-be adopted technology" for learning [Adams et al. 2016].

Several and worth noting AR systems are now available to the general public [Pellas et al. 2018] and a wide range of free mobile applications created by using "tools" such as Blippar and HP Reveal because the use of such tools allow users to create and share an overlaying digital content anchored to real-world objects [Blippar 2018; HP Reveal 2018]. Both AR "tools" can give a new option within their suite of digital features/elements, adding 'target tracking' to a physical object which will enable users to build AR experiences triggered by image content. Also, Blippar and HP Reveal do not require an extensive background in computer programming for their potential usage, trainee instructional media designers can build significant effects where they can place visualized 3D objects into physical objects and interact in real-time by adding target tracking capabilities. To this notion, users can have an immersive experience that is created as a "bridge" between physical and digital objects using, for example, a camera from a smartphone. Every "AR target tracker" enable users to develop persistent AR experiences tied to images, logos, and signs directly from real-world contexts. Applications capable of providing information on a specific object or location using visual markers are widely utilized in museums, art exhibitions, field studies (e.g., identification of plant species), educational settings [Alakärppä et al. 2017; Tobar-Muñoz et al. 2017] or other general purposes [Lytridis et al. 2018]. Likewise, research evidence suggests that AR can increase student motivation in the learning process [Bujak et al. 2013; Liu & Chu 2010], promote the user's state of "optimal experience" (flow) [Chang et al. 2014], thus contributing positively to the overall learning experience [e.g., Chen et al. 2016; Sommerauer & Müller 2014].

Notable works on the use of AR applications have also been made in mathematics. Bujak et al. [2013] have presented a framework for understanding AR learning from three perspectives. The first is the "physical" dimension that allows the manipulation of natural interactions and the creation of embodied representations. The second is the "cognitive" dimension. It provides information on how the spatiotemporal alignment of information through AR experiences can aid student's symbolic understanding to improve the understanding of abstract concepts. The third is the "contextual" dimension in which AR technology can create possibilities for collaborative learning around virtual content and in non-traditional environments. Cascales-Martínez et al. [2017] have suggested several reasons for the use of AR technology with a tabletop that can become more effective for instruction than the traditional approaches. The same authors also argued that a tabletop is shown as an artifact that can offer new ways of interaction. Salinas et al. [2013] have reported that the use of AR technology in the educational process through a didactic prototype can promote visualization skills related to the learning of mathematical content. The pilot experience confirmed that AR technology in education increases the current motivation to learn by students and serve as a platform that improved their learning performance due to the use of visual and tangible mathematics applications. Empirical evidence was provided in the study of Sommerauer and Müller [2014], AR technology has the potential to be an effective tool for learning formal contents (mathematics) in informal learning environments (museums). A significant point of view was that even inside informal settings, visitors learned significantly more from augmented exhibits and wish to see more AR experiences. Also, two studies have proposed design guidelines and a description of how can be created AR-based interactive games for mathematics. Firstly, Lee. H. S. and Lee, J.W. [2008] have provided a mathematical education board game for kindergarten and elementary students with the purpose to extend user's experience and to increase the usability of the system. Secondly, Radu et al. [2016] have discovered educational AR applications for mathematics by prototyping them at an elementary school level.

Recent advances in technology and instructional science have proposed alternative directions for education research with AR. A problematic topic is related to instructional-pedagogical issues. The institutionalist pressure in increasing tuition costs and fees, interactivity alongside with natural fidelity have offered by innovative technologies such as AR in several learning subjects have opened a new discussion about any changes that can be made in the traditional class instructional settings. To study the educational potential of AR technology, Pellas et al. [2018] have conducted a literature review with the following major findings: a) the support on several instructional design methods or models based on theoretical foundations; b) the scientific construction and understanding of knowledge and learning objectives; c) the effect and/or effectiveness of AR applications had on student engagement following different teaching approaches; d) the students' learning gain based on their increased performance through AR with game-based conditions.

Although the above educational potentials are yet provided as noteworthy, Pellas et al. [2018] have also pointed out some disadvantages regarding the use of AR technology in educational settings. These are as follows: a) students seemed to pay considerable attention to virtual information (novelty factor), b) teachers will not find so easy to develop every time additional learning material exclusive to the AR needs, and c) educators and instructional software developers sometimes create more complex AR systems which may cause a modest learning curve. Thence, two significant movements that educational systems should correspond to technological involvement inside classrooms. Such an involvement enables the amplification of information at an extremely cost-effective statement with AR.

According to the above, a notable option using AR applications can be inside a classroom in which students can interact with the appropriate learning materials using visual objects and features in order to conquer the knowledge rather than being passive receipts of their teacher's instructions. Given the research expectations that many educators and scholars with a focus on the learning approaches following curriculum guidelines, they tend to pay more attention to invest the time and effort which can spend through conventional lecture-based teaching approaches. Therefore, an instructional approach should aim to best utilize technology inside the classroom and foster trainees turning into problem-based learning tasks where they have an active role in order to understand course concepts.

2.3 The Role of Instructional Media Designers

Instructional media design courses are focused on the creation of digital (interactive) learning environments which can offer effective training approaches to several learning subjects. Such courses allow instructors to choose all those appropriate learning materials to assist students to accomplish certain tasks that they were previously unable to do [Reigeluth 2013]. With the increasing number of Information and Communication Technologies (ICT), instructional media design, as an educational domain at a university level, has recently gained further attention. The main reason is due to the use of various technologies which are widespread in this contemporary era and all can involve (trainee) instructors with (or not) computer literacy background. Thus, they can increase their professional development and skills with the use of innovative technologies to achieve any learning objectives and requirements for a variety of educational courses by designing, developing, and implementing content to meet those objectives. Various learning materials are extensive today and entail all those educational tools which are usually being utilized inside classroom ranging from digital slide presentations, videos, and podcasts to game-based environments. All learning tools and materials when are properly utilized with ICT can transform information into clear and meaningful content, thus affecting positively students' levels of engagement, satisfaction and finally their performance in overall [Kazanidis et al. 2018b].

Generally, a widely accepted instructional approach in different educational subjects is the "conventional" (face-to-face) that includes many times long lectures with little integration of practice-based, technology-focused tasks to be applied the gained knowledge in several learning subjects. Nevertheless, exposing younger students to content materials in long lectures can become ineffective for conceptualizing and understanding the notions being taught [Lee & Tsai 2011]. An exemplary teaching can foster media-instructional competencies of instructional media designers in training for the successful integration of AR applications for educational purposes implying on several aspects. The instructional media designers in training sessions acquire the competencies for a meaningful and successful implementation of several learning tasks that can be integrated into certain learning subjects. In specific, contributing to the aims of schools and curriculums, instructional media designers need to develop and disseminate innovative teaching practices. Such an approach requires the development of teaching, instructional methods and assessments in the school/university unit including planning, designing and developing objectives and material, they need to develop and create their own learning materials that can support student accreditation activities within different learning subjects [Kazanidis et al. 2018a].

Notwithstanding that the extensive use of learning technologies is aligned with the use of the most innovative one as something that can trigger students' attention, it is arguable if such technologies alone can satisfy their expectations in learning or create the most relevant climate inside a classroom which can increase not only their motivation but also their learning performance. For example, several are the potential constraints that are identified. In his study, Caswell et al. [2008] have already noticed that school classroom constraints on time and support due to the scarcity of technological support, limited resources, and lack of experience are the most crucial factors preventing instructors' professional development. Therefore, there are limited opportunities to gain the technical skills and confidence which they need in order to apply effectively their learning strategies operating as grave barriers in using ICT tools to their full capacity. To this notion, further studies need to provide evidence on how instructional media designers should come to propose their answers to overcome all those constraints.

According to all the aforementioned, in an effort to foster a well-considered and self-determined use of AR technology, instructional media designers should firstly consider instructional approaches with a wide range of requirements. They need to be trained and known efficiently which students' previous experiences are, what they are expecting, and an innovative technology related to the training of necessary competencies from an interdisciplinary educational perspective. Moreover, there is a vastly underexplored space that regards the experiment about the use of AR technology in several learning subjects. Worth noting to explore is the combination of real objects with digital media might be facilitated by AR tools which may be useful for the development of interactive applications. Hence, educational training programs should include the targeted promotion of competencies related to the fields of instructional media, together with basic technical knowledge and fundamental knowledge about the field of human-computer interaction.

3 Research Methodology

3.1 Setting

The objective of the current exploratory research is to gather preliminary information that will help researchers and scholars define problems and suggest hypotheses regarding the use of AR applications in mathematics. It is focused on the exploration of ideas and insights as opposed so as to collect statistically accurate data from the trainee instructional media designers' (aka participants) side. That is why exploratory research was best suited as the beginning of the current research plan. A rationale behind the use of such a research method is because it can provide information based on a study of the role of AR applications as an educational technology effective. Such a research approach can give the potentials about any further improvements in terms of quality of AR technology within specific projects in mathematics based on pre-service instructional designers' experiences and perceptions.

3.2 Participants

The sample comprised 16 females (M_{age}: 20.57, *SD*: 1.31) and 62 males (M_{age}: 21.74, *SD*: 1.17) volunteered to participate in groups of five people. All participants were undergraduate students who were enrolled in the first-year module called *"Instructional design and learning theories in Informatics"* at the Computer and

Informatics Engineering Department of Eastern Macedonia and Thrace Institute of Technology. Despite the significantly fewer female participants, the sample is regarded as acceptable, since this gender ratio is typical in Greek ICT-focused undergraduate courses and a balanced sample would have been either too small or unattainable.

3.3 Instrumentation and Data Collection Tool

The current study has followed a mixed-methods study was followed to bring the strengths of research forms so as to assess participants' experiential dimensions and to validate its results. Therefore, at the end of this teaching intervention, a close-ended self-reporting questionnaire response of participants was utilized to gather any quantitative data [Bargas-Avila & Hornbæk 2011]. All participants' answers were analyzed by following the guidelines that Tullis and Albert [2013] have proposed for user experience studies. Additionally, qualitative data were collected through open-ended interview questions to understand participants' enchantment and engagement using the proposed AR tools. Also, there were several options of writing short comments, albeit maintaining anonymity and confidentiality of all participants was ensured and remained. All questionnaires and interview questions were translated into Greek

In particular, all statements of this study's questionnaire to be measured learning experience had specific points of view rated on a 5-point Likert scale [strongly disagree (1) to strongly agree (5)]. It was constituted from 16 questions which separated as follows: learning effectiveness (LE), learning procedure (LP) and user experience (UX). Subparts about participants' learning outcomes and experiences concerned with issues that are ubiquitous in respective work; in specific, all identified aspects (aesthetics of interaction engagement, usability, usefulness, visual appeal) related to user experience [Bargas-Avila & Hornbæk 2011]. Cronbach's alpha (α) for each dimension was 0.835, 0.811 and 0.796 for LE, LP, and UX, respectively, reflecting on a reasonable internal consistency of the variables to describe participants' expectations.

Based on the above, analysis and findings extracted by summarizing the collected data following: (a) the guidelines of usability metrics from Tullis and Albert [2013], to access their learning experience using the proposed AR tools to create their own applications for mathematics including each user's response into the top-2-boxes (positive responses) or the bottom-2-boxes (negative responses), and (b) probing questions from the instructor provided feedback by posing questions to each participant when s/he seemed to get confused about helping them find an adequate direction to propose a solution.

3.4 Procedure

This study was conducted in an intensive 11-week period with 6 sessions. The sessions were taken place every two weeks and lasted 2 hours in face-to-face lectures during the spring semester of 2018. During these two weeks, students could communicate with the instructor, informed about the assignments and have access to any appropriate educational content via Moodle.

To attain knowledge through authentic learning experiences in the area of mathematics, participants were put into the real-life situation of producing content for an existing textbook. Specifically, participants were assessed on 4 practical assignments, which included the production of educational content for the first year of high school mathematics textbook used in Greek education secondary schools. The participants were divided into 5-member assignment groups. Each group assigned with specific learning sections from the mathematics textbook. All groups should produce supplemental learning material enhanced with AR technology. All of them had two week period to work on every assignment such as a) educational video development for theory instruction, b) worksheet creation with the development of new exercises, video and audio hints for textbook and worksheet exercises, c) utilization of the previous educational material using two different AR tools for creating their own applications and d) assessment of educational materials where participants had two weeks to improve their work based on the formative feedback they had received from their peers and the instructor during and after the completion of each assignment. Additionally, they were required to produce a report on the augmentations that they had applied to their projects.

In every lecture, the instructor explained to all participants what they have to do and presented them how to do it, providing best practices and all the appropriate educational material. To all other lectures, participants had two weeks period to complete their assignments. At the first lecture, the instructor informed participants about the learning goals of the course and the procedure that they had to follow (Figure 1). In this phase, participants were divided into groups of 5 members and one section of the mathematics book was assigned to them. During the next two weeks, they should study the content of the assigned section in order to be ready for the next assignment that will require knowledge of the appropriate learning domain.

At the second lecture, the instructor presented basic methodologies that have proposed by [Moussiades et al. 2017] on how to make an effective educational video. Students were asked to implement in groups two or three educational videos to present specific content related to the mathematics textbook that students in the secondary education use[3].

The third lecture was devoted to the construction of exercises and worksheets that can be later used as triggers for applying several augmentation techniques using the proposed two AR tools (Blippar and HP Reveal). Every group was asked to create a worksheet with adequate mathematical exercises and create another five to six videos explaining how someone can solve these exercises using their worksheets and textbooks. At this assignment, participants had to work both in groups in order to construct the worksheet and as individuals in order to develop at least one educational video. To all instructional lectures, a skilled tutor to the AR technology was the main administrator who presented every theoretical and practical instruction to all participants.

[3] https://www.youtube.com/channel/UCnVDmgCsUnIOWTciTkWUN7g/videos?view_as=subscriber

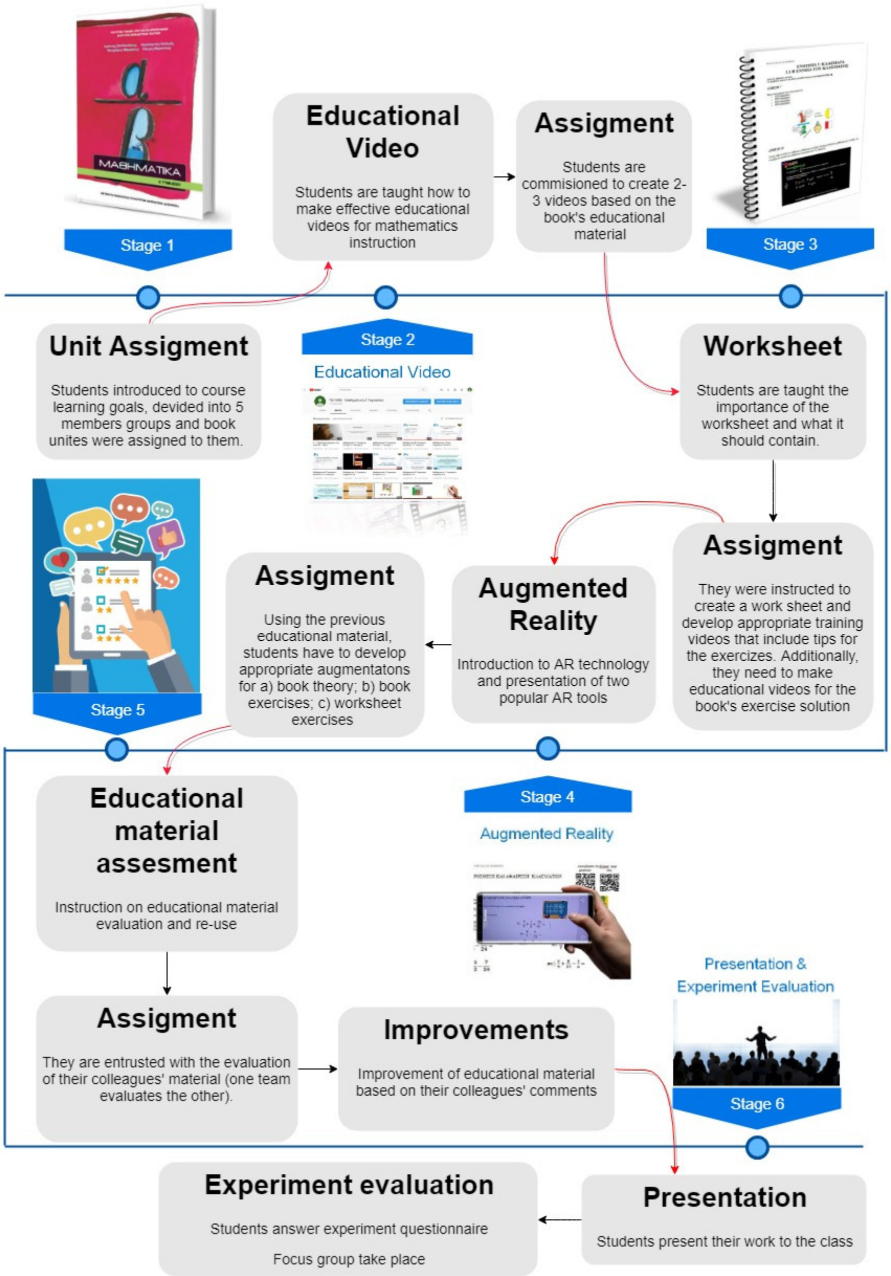

Figure 1: The learning procedure

At the fourth lecture, participants were introduced in AR technology, platforms, and tools. In addition, they should work with the two AR tools (Blippar and HP

Reveal) and they were further explained so as to be able to use them and apply their AR augmentation techniques. This was the most crucial part of the present teaching intervention since all participants had to utilize all the previous learning material that they have developed and enhanced it using AR technology. At this stage, every participant has to implement at least one AR application per tool. Any AR application had to augment either the content of the mathematics textbook section that was assigned to their group or the predeveloped exercises worksheet.

At the fifth lecture, a brief introduction of the educational material evaluation was given, and participants were asked to collaboratively assess as a team, in a one-week period, their peers' augmentations and developed educational videos and worksheets. They were needed to use and test the developed AR applications (Figure 2) with the following three criteria: *a) Does the trigger images work well and allow augmentations to appear without a problem? b) Does the augmentation content appear properly (in terms of displayed position and size)? c) Does the augmentation material provide useful and adequate information based on the assigned book section or exercise?*

At the end of the fifth lecture, participants had the chance to submit their report as a group with their outcomes, suggestions, and comments. At the end of each stage, the instructor was assessing participants' assignments and was providing feedback to them so as to improve their assignments and learn from their errors/mistakes.

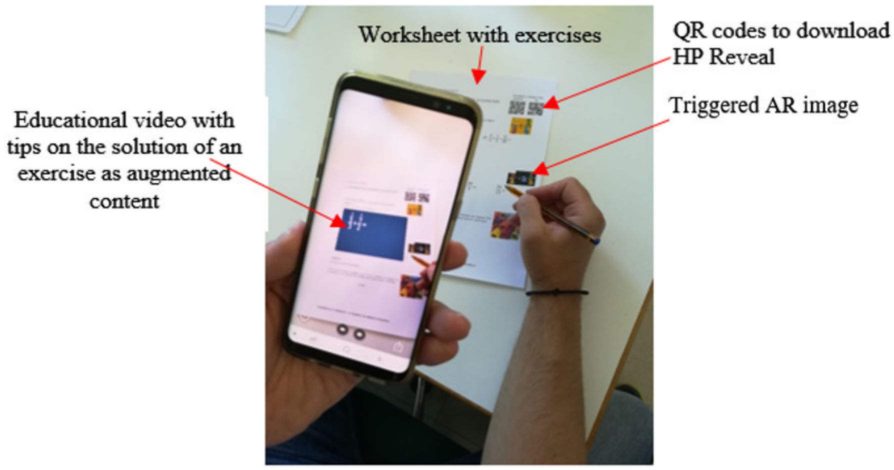

Figure 2: An example with a participant who tries to scan a worksheet of another team using HP Reveal

After the end of this teaching intervention, the assessment results were shared through the educational platform and participants had another one week to improve their augmentations and developed material according to their peers' comments.

At the final and last session, each group presented at the class what they have done. Furthermore, they tried to answer an assessment questionnaire and after that a focus group discussion took place.

3.5 Experimental Setup

In the experimental setup, participants were needed to effectively collaborate and create appropriate educational videos and applications regarding AR augmentation techniques. To complete all tasks, they should follow a given methodology for educational video development [Moussiades et al. 2017], create AR capable worksheets and use two of the most popular AR applications in order to create their augmentations. Regarding the construction of augmentations, they should use the provided web-based authoring tools and upload correctly the augmentation material, defining the trigger images and explain how this content will be provided to the user.

In the present experiment, the trainee instructor media designers created learning content or material for mathematics courses using AR tools without advanced knowledge in computer programming. Several elements need to be referred to figure out this procedure. These are the following: a) study of the subordinate modules; b) study of creating effective educational videos for teaching mathematics and create two or three videos based on a textbook material; c) learn about the meaning of creating worksheets and what they should contain. They entrusted with the creation of gender-equal tasks by developing educational videos with proposals for their solution that would later become AR applications. Apparently, they should make educational videos for textbook's exercise solutions that are utilized in the Greek secondary education; d) propose and use AR applications to enhance Educational Technology context with a focus on mathematics. The use of all previous material is required to develop their applications related to the appropriate augment techniques using Blippar and HP Reveal for (i) book’s theory related to mathematics concepts and functions, (ii) book exercises, (iii) worksheet exercises; e) assess the educational material in order to enable younger students to choose and reuse free educational material. They are entrusted with the evaluation of their colleagues' material (one group evaluates the other), f) improve of the learning material and content based on the comments of their peers and presentation of their videos and AR applications inside the classroom, and lastly g) fill any experiment questionnaires and participate to a focus group discussion

4 Results

Regarding the participants’ background based on demographic information, about half of them (55.1%) did not know what AR technology is. In their majority (66.7%) they have not got experience with any AR application before attending this teaching intervention, while almost all of them (95%) have a smartphone. Some of them (20.5%) had previous experience with AR development tools like HP Reveal and had utilized them so as to create their own augmentations and applications. Specifically, all participants who performed their AR applications (76/78, 97.5%) had specific objectives to achieve with the formulation of specific mathematical problems and their final presentation through AR technology. They also seemed to understand clearly how the present instructional intervention why the use of AR technology was made and for what reasons. Most participants had satisfactory performance and performed really well in the 4^{rth} instructional phase, i.e. 83% (65/78) instances performed really well in the 4th stage of this instructional intervention.

Regarding LE, many participants reported several points of view about the learning effectiveness of AR technology using Blippar and HP Reveal (Figure 3). Most of the participants (51 out of 78) were able to use AR technology for the formulation of mathematical problems, with 56 out of 78 (72%) participants who used the AR tools seemed to understand the use of the provided features. Almost up to half participants 65.3% (57 out of 78) understood how to apply step-by-step their augmentations while most of them 57% (45 out of 78) have improved their augmentations after their peers' suggestions. One participant reported that *"Some facts using HP Reveal are really represented well. This helped me not only to rationalize my decisions by applying and explaining my solution but also to know why I used some mathematical concepts and sub-parts of problems that I would like to represent in my application"*. Another one said that *"Blippar is a really good tool and now I can apply my augmentations easily, as I visually saw the results of my AR application design inside its authoring tool"*.

In contrast, others had some difficulties to get used to the authoring environments of the AR tools reported in a small percentage of 4% (3 out of 78) confusion on their proper usage. One of them was complaining that *"Sometimes I was not able to recognize which type of augmentation exactly to use when I have applied my augmentations without having the appropriate background in computer programming"*.

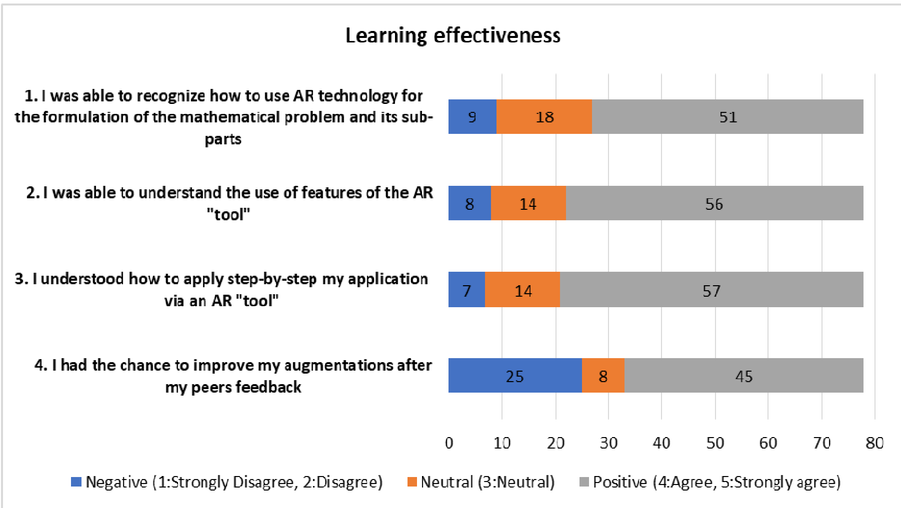

Figure 3: Horizontal stacked bar chart of top/bottom-2-boxes of user responses about the LE

In terms of LP, again many participants were at the top-2-box scores. Ranking percentage based on their answers reported that 78% (60 out of 78 participants) succeeded in applying their augmentations for the main mathematical concept that was assigned to their team and 72% (56 out of 78 participants) were able to explain why they used specific mathematical concepts and exercises. A lot of them 84.6% (66 out of 78) were able to understand both instructor's feedback and their peers' feedback when this was provided. However, it seems that relatively fewer users 48% (38 out of 78) seemed that effectively applied a solution through appropriate design of their augmentations. They believed that they were not experienced well in order to be able to choose an appropriate design. One participant referred that *"There are so many options and ways to apply AR innervations, I feel frustrated even to choose the appropriate multimedia type."* Additionally, 57.7% (45 out of 78) of the participants felt that they can effectively apply and execute their AR applications after this teaching intervention.

From the above results (Figure 4), it is quite clear that most participants had a positive view of the learning procedure. The integration of the implemented educational material through AR was referred by participants as an important issue, especially because it enables them to create "innovative" learning procedures through a motivated process: *"Blippar enabled me to provide the appropriate educational material through an innovative way", it was motivating to create AR applications that change the traditional study to an enjoyable process".* Another one participant referred that *"the instructor guided my practices and he helped me with the implementation and the right use of HP Reveal tools in order to apply without using a computer programming language my planning and visualize correctly my application".*

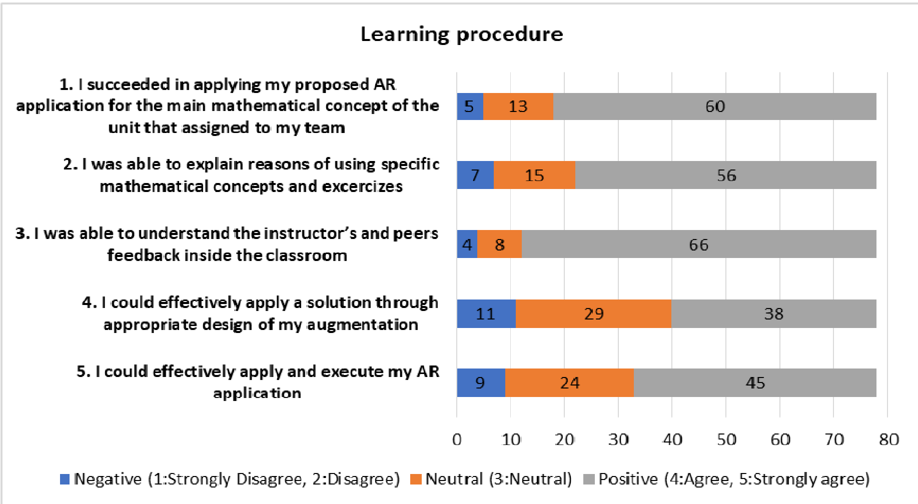

Figure 4: Horizontal stacked bar chart of top/bottom-2-boxes of user responses about the LP

With respect to the UX, most participants were at the top-2-box scores (Figure 5). For instance, the top-2-box score is 87.2% (68 out of 78) of participants found the AR applications visually appealing, while at the same time 67.9% of them agreed how helpful was the provided authoring features for building AR applications. Additionally, 56.4% of the participants (44 out of 78) consider the AR tools as useful for mathematics instruction and a similar percentage of 53.8% (42 out of 78) generally appropriate for creating educational interventions. Finally, 73% believes that AR combined with the textbook is easy to use.

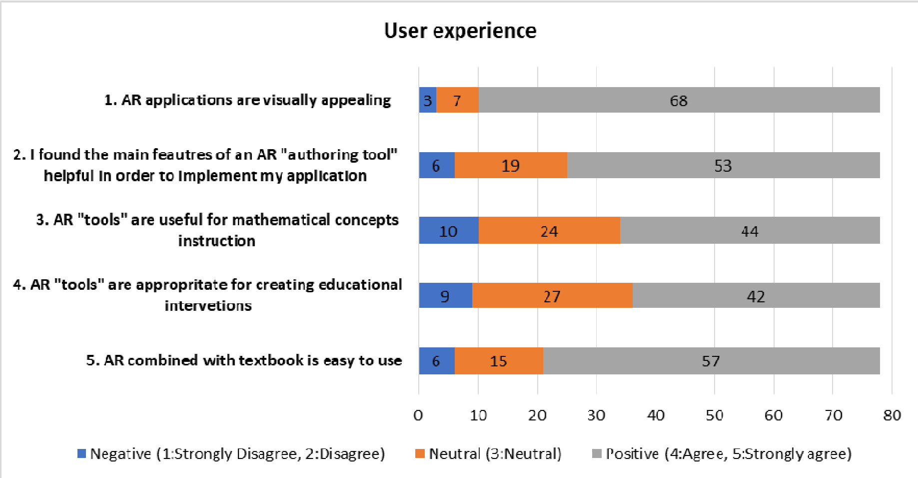

Figure 5: Horizontal stacked bar chart of top/bottom-2-boxes of user responses about the UX

Participants have reported on several aspects of the use of AR, which contributed to a positive user experience. A representative answer reported that *"Both AR tools are easy to learn without knowing computer programming or having previous knowledge on the domain"*. Other one said, *"Three weeks ago, I couldn't imagine that I will have the opportunity to create AR applications. My augmentations were for mathematics fractions and I am proud of succeeding in it"*.

In the focus group session, a short discussion with the participants revealed some more aspects regarding the use of the AR technology for mathematics Instruction. Most of them were excited about AR technology and they mention that they are going to use it in other aspects as well. Others reported some issues with team collaboration and point out that a collaborative AR authoring tool could be very useful in such cases. Most of the participants expressed the opinion that as future teachers, will definitely use AR technology. When discussing the availability of authoring tools using AR applications, three participants mentioned that they already looked for more powerful tools for AR application development such as Unity 3D in combination with Vuforia. Most of them indicated the AR assignment as one of the most enjoyable exercises of this course in the present semester. Nevertheless, they felt that educational video development assignment was the most time consuming and hard to do. They also argued that a teaching procedure for educational content development is adequate for mathematics and other STEM courses. In addition, a number of participants reported specific technical issues during the implementation of their applications. Most of the times these problems were solved with the assistance of their teammates. In some other cases, the participants contact the instructor in order to help them.

The discussion in the focus group pointed out also some negative aspects of such an experiment. A small number of participants reported that they would require more time to absorb the basics of this course and to get familiar with the proposed AR tools. Other 3 participants were reported about the effectiveness of the proposed AR tools and specifically for the image marker recognition as they said that *"sometimes when I tried to make an AR application triggered by a specific book page, the AR tool could not recognize the trigger image and the augmentation never appeared".* Few users were complained about implementation issues and in particular on the appropriate multimedia content development for the augmentations. For example, one said that *"I think that if we want to create professional AR applications, we need content such as 3D objects and animations that are difficult to develop by a non-designer user."*

5 Discussion

This study's results revealed that AR applications can provide an acceptable instructional approach that seems to be really promising in mathematics. Almost all participants described the design of their own applications as motivating with potential opportunities to provide on younger students in order to acquire knowledge in mathematics courses. They also pointed out that AR technology in continuously using can provide high interest on the one hand. On the other, are considered as alternative "mediums" on the use of innovative technologies inside classrooms. Instructional media designers have learned to overcome any technical problems, an ability which can be regarded as important for the dealing with potential technical issues which could prevent the efficient intervention of such a technology inside classroom settings.

All applications from the designers indicate that they have learned to identify suitable topics and appropriate instructional approaches related to concepts in mathematics based on the successful integration of AR applications. To succeed in such an educational program, the course instructor needs to provide not only well-designed instructional conditions which are related to the authentic experience of AR technology but also to be able to use such technology effective for mathematics. In specific, the latter seems to be imperative since such a skilled instructor can always have the teaching time and experience to provide the appropriate feedback to all other instructors and to this notion guiding more effectively such an instructional approach in order to avoid any inappropriate or frustrating learning tasks.

The present study corresponds to the findings of previous ones [Nadonly 2017; Pellas et al. 2018; Wu et al. 2013] about teaching approaches, in which instructional designers should follow to understand main reasons of using AR technology in a learning subject, such as in this case mathematics. Findings of this exploratory study unveil that a great number of trainee instructional media designers found the development and assessment of AR applications fascinating and the technology very promising and useful for mathematics Instruction. Using free and easy to use tools for non-programmers' (instructional media) designers for developing AR applications appeared to have not any difficulties in producing some good problem-solving applications for mathematics. Consistent with previous studies findings [Bujak et al. 2013; Salinas et al. 2013; Sommerauer & Müller 2014], an AR application is regarded as a reliable medium for participants to focus more in problem-solving learning tasks by applying more succinct and precise mathematical concepts and fractions. Such a process can give valuable answers for assessing how students try to think and practice “mathematically”. This can also give evidence of a deeper understanding from the description of how correctly a cognitive thinking process in practice for the comprehension and production of any solutions can be provided into code.

To summarize, this study argues that AR applications which combine physical with digital features and objects for a more natural-intuitive modality for user-interaction tasks according to the instructional media designers’ answers can assist younger students to understand better problem-solving situations in mathematics. In this perspective, this study is in the line of reasoning from future outlook or limitations which have been previously mentioned from other studies [Pellas et al. 2018; Wu et al. 2013] about the integration of AR inside school classrooms. For example, this study gives potential answers about the learning affordances of applications created with AR tools such as Blippar and HP Reveal, it gives experimental evidence about user experience and perceptions of instructional media designers on how AR can influence students’ problem-solving strategies in mathematics courses.

6 Conclusion

Since the digital access and availability of tools continue to advance at an extraordinary rate during the last decade for educators to design learning tasks with AR, there is an increased need for research-based best practices in design. Hence, the purpose of this study was to investigate the effectiveness of the AR technology in mathematics courses according to instructional media designers who develop and produce applications with learning content sufficiently for students with different socio-cognitive background and gender. This study’s results from the instructional media designers’ side revealed that AR applications can provide affordances and potentials to make the educational processes more active and interesting. So far, it confirms that there are appropriate and available authoring tools for developing AR applications even for non-programmers’ (trainee) instructors or those who have little background in computer programming. These tools are easy to use and provide adequate features to build effective AR applications.

The current study presents results from an instructive-guided approach in which AR applications were created by instructional media designers who tried to foster their competencies with the purpose to be integrated learning material in mathematics courses. Specifically, this study provides empirical evidence regarding the perception of the processes for developing, implementing and assessing their AR applications with sometimes controversy opinions. Overall, the results indicate that the use of AR applications can be potentially valuable for the successful training of instructional media designers in regard to the integration of AR and foster their competencies for IT skills integration. The use of such AR applications is regarded as potentially valuable for the stated learning goals of mathematics. Instructional media designers’ answers revealed the positive acceptance on how instruction using AR applications can be achieved due to their satisfactory performance and experience in favor of engaging students through innovative and interactive learning tasks. The results have given a clear picture that both the visual design and instructional guidance had a positive impact on user interaction and performance with AR applications. It is proved that designers not only did all these choices which are resulted from their different experiences but also the utilization of AR tools was the most significant factor that has greatly increased interaction with digital-oriented visual objects. Thereby, it is imperative to refer the fact that this study has successfully explored the research "gap" using AR technology in mathematics from the instructional media designers' side; however, the research focus was not to assess AR as a generic technology.

From an instructional-educational perspective, two of the most notable implications for practice that need are as follows. First, features and elements of the AR tools supported instructors to map out subparts of the main problem to a great extent, as they were able to configure points by exploring and understanding the consequences arising from choices made in every AR applications given the appropriate feedback to users' actions. The natural intuitive modality for user interaction through AR-based learning tasks seemed that assist users to think and transform alternative fractions through interactive learning tasks in order to apply more accurate mathematical concepts and practices. Second, the representational visual elements and features created without being all participants experts in a computer programming related to the users' awareness. This allowed them to study multiple traces threads and considered several alternative choices that could be taken seriously into account for spotting and solving subparts of the main problem using skills related to IT. This implies easier the transformation of innate thinking to be proposed a solution with accurate instructions and mathematical fractions (or concepts) that can be assisted by several simulated problem-solving features and elements.

However, from a methodological-educational perspective, this experimental setup has several downfalls regarding the use of AR as a multimedia tool as trainee instructors have mentioned. First, testing activities by just triggering any static content needs to be included and organized into well-structured instructional settings in order to be properly tested and be proposed any development methodology. Second, the use of hard copies cannot always assist students to avoid the "steep learning curve" due to high novelty effect on the use of a smartphone and its applications. Third, any further test criteria for timeliness and robustness need to be based on pre-defined points which are visually appealing and can lead students to automatically generate test cases as sequences of triggering events for executing their personal augmentations. Therefore, a significant consequence of all these downfalls is that many suggested augmentations should be sufficiently validated in practice and specifically inside real school-age context (e.g. classrooms) with the respect to be validated further the applicability of such AR applications.

By synthesizing the findings from this study, a set of design guidelines and recommendations building upon the experience gained from subsequent design and assess are the following:

- Developing and designing certain activities with specific learning tasks using AR tools can afford trainees on instructional media design not only to challenge with logical reasoning thinking but also affect their critical thinking skills supported by an additional visually-rich interaction that is provided and with the appropriate feedback based on user's actions.

- Immersing students' learning experience requires not the utilization of abstract concepts in which can be freely developed anything, but specific ways in which certain tasks can be applied.
- Reducing the "steep learning curve" using mobile devices during the learning process should include firstly the instructor's feedback to all user's actions until s/he takes any important information. Also, to lower the complexity of sub-tasks is required to achieve each user the main learning objectives following the scopes that each country's curriculum requires.
- Educational sectors and providers can improve the quality of their conventional instructive-guided support inside the classroom with AR interactive digital-oriented materials following project-based practices and utilizing "tools" that lower the syntax complexity of computer programming languages so as to create software applications that can provide feedback and support visually and/or acoustically users' actions.

Understanding the learning expectations and experiences of instructional media designers for a new and immature technology like AR is a challenging topic that international literature has not yet extensively discussed. Therefore, this study contributes to the field of educational technology using AR, since it gives new insights into the user expectations and perceptions of instructional media designers who want to utilize AR technology in mathematics. Through the current user experience exploratory study, the results from an empirical study were able to elicit the development and design level needs in regard to AR technology. Consequently, the contribution of this study is fourfold. Firstly, it gives advice and suggestions to educators and scholars who want to incorporate AR technology and its "tools" for the design and development of innovative augmentations into their teaching practice in mathematics courses. Secondly, it offers researchers insights about instructional media design courses through an exploratory mixed-methods study on user experience using AR "tools" for non-programmers. Thirdly, it provides empirical evidence on how well-designed instructional activities can potentially increase students' academic performance and satisfaction. Fourthly, it suggests a set of design guidelines and recommendations building upon the experience gained from subsequent design and evaluation of instructional media designers' experience and expectations to support more effectively several concepts in mathematics.

To conclude, the present exploratory study supports the opinion that using AR tools such as HP Reveal and Blippar can be developed some of the most indicative applications which can offer high-quality digital-oriented learning content to educators' hands. Since the field of AR interactive applications for the STEM is in its early stages, educational providers, researchers, and technologists need to stay "tuned" on any extension related to VR/MR technologies in order to develop innovative applications which can really improve knowledge acquisition and transfer for students with a different socio-cognitive background in this field.

7 Limitations and Future Work

This section presents some of the most notable limitations. The first limitation is that this study does not address the lack of evidence in regard to alternative ways of learning mathematics. For example, it does not follow recommendations of Powers and Blubaugh [2005] who have proposed that learning needs to be focused on students' skills progress from basic to more complex levels of knowledge. The assessment of each student can be aligned with well-designed learning tasks having specific objectives to be aligned with overall goals for learner progression and autonomy or to be aligned with the scopes that each country's curriculum requires.

The second limitation is that this study was not so clearly identified to what extent AR applications created by instructional media designers had the potential to improve (or not) students' learning performance. In other words, it is not clear if another kind of real-time/interactive feedback either from the main instructor or from the learning applications would benefit students' achievements in mathematics. This limitation relates back to Irving [2006] study's debate in which the appropriate use of technology inside specific instructional approaches can impact learning achievements and not the technology alone inside an instructional approach itself.

The third limitation goes to the issues of the "knowledge transfer" and the generalization of this study's findings. It cannot be recognizable to what extent AR-based applications would be successful in other learning tasks for young students or whether AR instructional approach might also work with older ones or in different kinds of learning tasks.

The fourth limitation is the small number of participants (n=78) from only one sector. This may cause lack of investigation into other identification or insights from tasks that can potentially be involved in the targeted group with instructional designers who can develop AR applications compared with other users who may have the different socio-cognitive background, gender and/or more advanced background in programming. Such studies should determine different ways that students try to acquire knowledge and how AR technology can satisfy their demands and needs. In this study, it was out of its' purposes any comparative perspectives on pre/post-tests analysis, and thus the persistence of learning is relatively unanswered.

Several variables can potentially affect this study's results. Such variables may reflect contextual factors such as usability, different user socio-cognitive background characteristics of participants, and/or theoretical foundations or instructional models that can improve (or not) on the users' learning experience [Nodonly 2017; Wu et al. 2013]. It is important for researchers to adequately describe the learning context for adequate interpretation of research results. This study addresses these challenges by using recommended methodological techniques within a large data set of user interactions and a thorough examination of educational applications created for mathematics. Also, it seeks to provide a pathway in using effectively AR "tools" to provide much-improved feedback during several learning tasks in mathematics.

While this study informs about trainee instructors' experience and perceptions on the use of AR technology, there is certainly much more to investigate other future works. Future works need to investigate issues that mentioned earlier to strengthen the reliability of experimental design using longitudinal studies with long-term analysis of the learning experiences alongside a larger sample. Furthermore, other studies should include pre-/post-tests for a larger period of time. Such studies can be important in this research field in order to see to what extent the intervention of HP Reveal and Blippar resulted in stable and persistent learning outcomes and performance. Such an effort can also provide important insights into the suitability of interactive AR-based applications for interdisciplinary learning in STEM subjects.

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