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EVALUACIÓN DE APLICACIONES EDUCATIVAS DE AR CON ESTUDIANTES ADULTOS

TESIS DOCTORAL
Presentada por
Konstantina Sdravopoulou
Dirigida por
Professor Dr. Juan Manuel Muñoz González
Professora Dra. María Dolores Hidalgo-Ariza
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TITULO: *Evaluación de aplicaciones educativas de AR con estudiantes adultos*

AUTOR: *Konstantina Sdravopoulou*

Campus de Rabanales
Ctra. Nacional IV, Km. 396 A
14071 Córdoba

https://www.uco.es/ucopress/index.php/es/
ucopress@uco.es

TÍTULO DE LA TESIS: Evaluación de aplicaciones educativas de AR con estudiantes adultos
DOCTORANDA: Konstantina Sdravopoulou

INFORME RAZONADO DEL/DE LOS DIRECTORES DE LA TESIS
(se hará mención a la evolución y desarrollo de la tesis, así como a trabajos y publicaciones derivados de la misma).

El trabajo de investigación realizado por Konstantina Sdravopoulou que hemos codirigido entre los profesores Juan Manuel Muñoz González y María Dolores Hidalgo Ariza presenta, a nuestro juicio, es de suficiente indicios de calidad y rigor científico como para que sea presentado a defensa pública y evaluado en Comisión Académica en orden a la posible adquisición del grado de Doctor. Consta de cuatro artículos que ofrecen a la comunidad científica información válida para mejorar la calidad de la educación de adultos, utilizando juegos móviles de realidad aumentada, basados en geolocalización. Estos cuatro artículos han sido publicados o aceptados en revistas de reconocido prestigio y rigor científico, como puede verse en el informe sobre las indicaciones de calidad de la tesis doctoral. En esta tesis doctoral se ha realizado una revisión sistemática y actualizada de la literatura, evaluando la información científica disponible hasta el momento sobre el uso de juegos de realidad aumentada, juegos de realidad aumentada móviles y juegos de realidad aumentada basados en geolocalización en general y específicamente en adultos. En cuanto a la metodología, cabe destacar la combinación de nuevos métodos cualitativos y cuantitativos, como el análisis de contenido, el índice de similitud de Jaccard, métodos de Análisis de Redes Sociales y también el modelo ARCS. Una conclusión muy esperanzadora surge de los resultados del trabajo: la educación de los estudiantes adultos se puede mejorar a través de juegos de realidad aumentada móviles basados en geolocalización.
Por todo ello, se autoriza la presentación de la tesis doctoral.

Córdoba, 15 de Febrero de 2022

Firma del/de los director/es

Fdo.: Juan Manuel Muñoz González Fdo.: María Dolores Hidalgo Ariza

MUÑOZ GONZALEZ JUAN MANUEL - 30968058F
Firmado digitalmente por MUÑOZ GONZALEZ JUAN MANUEL - 30968058F
Fecha: 2022.03.17 11:06:09 +01'00'

HIDALGO ARIZA MARIA DOLORES - 30952308N
Firmado digitalmente por HIDALGO ARIZA MARIA DOLORES - 30952308N
Fecha: 2022.03.17 11:06:22 +01'00'

To my mother

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Table of Contents

List of figures

List of tables

Paper P4

Resumen

Resumen

Existe un creciente interés por las aplicaciones educativas de la Realidad Aumentada (RA). Mientras que la mayoría de las aplicaciones de estas tecnologías se han examinado en el contexto de la educación infantil, nuestro conocimiento sobre su utilidad en la educación de adultos es deficiente y, en particular, más en la categoría de juegos de Realidad Aumentada Basada en la Localización (LBMAR), por lo que el objetivo de esta tesis es examinar las opiniones de los estudiantes adultos (jóvenes, de mediana edad y mayores) sobre un juego LBMAR, el "Ingress". Los principales problemas que aborda esta investigación comprenden cuestiones relacionadas con la utilidad de algunos componentes tecnológicos de la RA en la educación (secundariamente) y con aspectos de la formación de adultos mediante el uso de la RA (principalmente).

En cuanto a los aspectos tecnológicos, es decir "¿cuál de los tres tipos de RA (basada en marcadores, sin marcadores, basada en la localización) se asocia más a los enfoques naturalistas y cuáles son sus ventajas relativas?", esta investigación demostró que los enfoques naturalistas aplicados a la RA basada en marcadores potencian la participación activa en entornos virtuales, motivan a los alumnos, promueven la implicación personal en la conquista de nueva información, ofrecen diferentes perspectivas del contenido y despiertan el interés por el conocimiento. En el caso de la RA sin marcadores, los diseños naturalistas fomentan la colaboración de los participantes en los juegos, mejoran la interactividad, ofrecen vistas panorámicas, visualización y la posibilidad de examinar los controles visuales. Además, los enfoques naturalistas aplicados a la RA basada en la localización son adecuados para el diseño de aplicaciones multidisciplinares, pueden utilizarse para la formación y tienen la posibilidad de diseñarse teniendo en cuenta la localidad y el contexto. El hecho de que, como se desprende de la literatura revisada por pares que se examinó, las tecnologías de RA basadas en la localización son más apropiadas para la educación y para los teléfonos smartphones, sugiere que podría ser interesante un examen más profundo de su utilidad potencial para la educación (y para la educación de adultos en particular).

En cuanto a los aspectos educativos, que también constituyen el foco principal de la tesis, éstos se centran en la exploración de la utilidad del juego LBMAR "Ingress" en la educación de adultos, respondiendo a dos preguntas entrelazadas: a) ¿cómo evaluar las opiniones de los alumnos adultos sobre el juego LBMAR "Ingress"? y b) ¿qué piensan los alumnos adultos sobre este juego y cómo perciben sus características?

Dar respuesta a estas preguntas equivale a recibir resultados adecuados de una investigación empírica, cuantitativa y cualitativa, que se diseñaría para explorar sus opiniones, puntos de vista y actitudes con respecto a este juego LBMAR. Por lo tanto, 45 personas adultas de Grecia, con edades entre 20 y 62 años, colaboraron como sujetos de esta investigación. Siguieron una breve formación informal introductoria por parte del investigador de esta tesis (sobre RA, realidad virtual, RA móvil, y sobre los juegos relacionados con estas tecnologías) y posteriormente se les dieron las instrucciones de cómo utilizar "Ingress" en un smartphone. La investigación cuantitativa se llevó a cabo antes y después de la formación y todos los alumnos participaron respondiendo a 31 preguntas cerradas del tipo Likert antes y

después de la formación. La investigación cualitativa se basó en el análisis de sus respuestas a dos conjuntos diferentes de preguntas abiertas. El primer conjunto constaba de 5 preguntas de este tipo (a las que respondieron 24 participantes) y el segundo conjunto tenía 2 preguntas más amplias, a las que respondieron 36 participantes.

La investigación cuantitativa mostró las ventajas para la educación de adultos de integrar el modelo ARCS en la fase de aprendizaje de un juego LBMAR. En concreto, se demostró que la utilización del conocido "modelo ARCS" de Keller (Atención - Relevancia - Confianza - Satisfacción) permitió clasificar las respuestas de los usuarios con respecto a sus interacciónes con el juego y, tambien, es útil para evaluar la educación de adultos con juegos LBMAR. Las respuestas de los jugadores no cambiaron linealmente con su edad y el entrenamiento ha tenido un impacto diferente en cada grupo de edad de los alumnos. Además, los análisis estadísticos demostraron que el entrenamiento aumentó las puntuaciones de los factores del modelo ARCS.

Otros resultados de esta investigación mostraron que los mayores de 36 años se centraron más en el hecho de que el juego "Ingress" es principalmente un juego geográfico y su escenario refleja interesantes debates sobre la evolución de la humanidad. Las opiniones de los participantes de los grupos de edad de 20-35 y >52 coincidieron en que el juego no tiene fases ociosas, que combina la emoción con la inseguridad y que es agradable jugar a nivel local a un juego de proporciones planetarias. Otra observación relacionada con la edad se refería a las respuestas a la pregunta ("¿Cómo te sientes cuando dotas al espacio geográfico de preferencias personales?") entre grupos de edad que coincidían: los dos primeros grupos de edad (20-30) y (30-40) estaban más de acuerdo que los dos últimos (40-50) y (50-60). Sin embargo, en la pregunta "¿Crees que el juego ofrece oportunidades para aprender y enseñar geografía, aprovechando tus conocimientos geográficos previos?" hubo un solapamiento en las respuestas de los participantes entre los grupos de edad. En cuanto a la primera pregunta, el concepto más crítico fue: "los usuarios sienten una especie de nostalgia", seguido del concepto "los usuarios consideran los portales como creaciones personales". En el caso de la segunda pregunta, el concepto más crítico fue que los participantes creen que el juego ofrece oportunidades totalmente nuevas para la educación en geografía en comparación con sus experiencias anteriores. Esto fomenta una evidencia de los enfoques constructivistas de la educación de adultos y, también, la relevancia de algunas otras teorías prominentes de la educación de adultos, como el humanismo.

Metodológicamente, esta investigación demostró tambien que el análisis de contenido es un método valioso para explorar las opiniones y actitudes de los usuarios adultos hacia los juegos MAR y los índices de Jaccard pueden utilizarse para explorar cuantitativamente los temas que surgen del análisis de contenido. El análisis de contenido se realizó sobre las respuestas de los usuarios de forma cualitativa para identificar las frases características que expresan actitudes y opiniones. Para la evaluación cuantitativa de las similitudes entre las respuestas de cada pregunta y subconcepto, se calculó el índice de similitud de Jaccard por parejas para cada par de participantes. Además de los índices de Jaccard y de ampliar el alcance de los nuevos métodos de análisis de contenido, esta tesis muestra cómo utilizar el Análisis de Redes Sociales (Social Networks Analysis - SNA) para modelar los mapas

conceptuales, abriendo así excelentes oportunidades para crear visualizaciones de los conceptos y sus interrelaciones. Los aspectos cuantitativos del análisis SNA (es decir, mediante el uso de la centralidad radial y la centralidad de la información) proporcionan mecanismos adecuados para medir las relaciones internas en los mapas conceptuales (además de la inspección visual) que de otro modo no serían visibles. El uso del SNA permitió la clasificación de las respuestas de los usuarios con respecto a su interacción con el juego y, por lo tanto, fue un enfoque fructífero para la educación que involucra los juegos MAR. Además, con esta novedad, se muestra cómo los textos derivados de las entrevistas o de las respuestas a las preguntas abiertas de diferentes individuos pueden ser analizados tanto cualitativamente como cuantitativamente usando SNA.

En conclusión, esta investigación ha aportado novedades, tanto a nivel educativo como metodológico. En lo que respecta a la educación de adultos, se ha demostrado que i) los juegos LBMAR son adecuados para ella, ii) la educación de adultos sobre ellos puede mejorarse siguiendo el modelo ARCS de Keller, iii) la percepción y la satisfacción de los alumnos adultos depende de la edad, y iv) ciertas teorías de la educación de adultos (es decir, el constructivismo y el humanismo) pueden ser relevantes cuando los alumnos adultos utilizan juegos LBMAR como "Ingress". En cuanto a los métodos de investigación educativa, esta investigación sugirió métodos totalmente nuevos para analizar los datos que se derivan de las respuestas de los alumnos a las preguntas abiertas. Estos nuevos métodos son el análisis de contenido de las respuestas de los participantes con el uso de los índices de Jaccard y los métodos de SNA y pueden tener una aplicabilidad más amplia a la investigación educativa.

Abstract

Abstract

There is a growing interest in the educational applications of Augmented Reality (AR). While most applications of these technologies have been examined in the context of children education, our knowledge about their usefulness in adult education is deficient and particularly more in the category of Location-Based Augmented Reality (LBMAR) games, so the aim of this thesis is to examine the opinions of adult learners (young, middle-aged and elderly) about one particular LBMAR game, the "Ingress". The main problems addressed by this research comprise questions relating to the usefulness of some key technological components of AR in education (secondarily) and to aspects of training adults by using AR (primarily).

As concerns the technological aspects, i.e. "which one of the three types of AR (marker-based, markerless, location-based) is more often associated with naturalistic approaches and what are their relative advantages?", this research showed that naturalistic approaches applied to marker-based AR enhance active participation in virtual environments, motivate learners, promote personal involvement in conquering new information, offer different perspectives of the content and arouse interest for knowledge. In the case of markerless AR, naturalistic designs foster participants' collaboration in games, enhance interactivity, offer panoramic views, visualization, and the possibility to examine the role of visual controls. Moreover, naturalistic approaches applied to location-based AR are suitable for designing multidisciplinary applications, can be used for training and have the possibility to be designed so as to account for locality and context. The fact that, as appears from the peer-reviewed literature that was examined, the location-based AR technologies are more appropriate for education and for smartphones, hints that a deeper examination of their potential usefulness for education (and for adult education in particular) might be interesting.

As concerns the educational aspects, which also constitute the main focus of the thesis, these focus on the exploration of the usefulness of the LBMAR game "Ingress" in adult education, by answering two intertwined questions: a) how to assess opinions of adult learners about the LBMAR game "Ingress"? and b) what do adult learners think about this game and how do they perceive its features?

Providing answers to these questions is tantamount to receiving adequate results from quantitative and qualitative empirical research which would be designed so as to explore their opinions, views and attitudes with respect to this LBMAR game. Hence, 45 adult persons from Greece, aged 20 to 62,cooperated as subjects of this research. They followed a short introductory informal training (on AR, VR, MAR and the games that are relevant to these technologies) by the researcher of this thesis and were subsequently given the instructions of how to use "Ingress" on a smartphone. The quantitative research was carried out before and after training and all trainees participated by filling 31 Likert-type closed questions before and after training. The qualitative research was based on the analysis of their responses to two different sets of open-ended questions. The first set consisted in 5 such questions to which answered 24 participants and the second set had 2 broader questions to which responded 36 participants.

This research showed the advantages for adult education of integrating the ARCS model into the learning phase of an LBMAR game. Specifically, it was shown that using Keller's widely known "ARCS model" (Attention – Relevance – Confidence - Satisfaction) enabled the classification of users' responses with respect to their interaction with the game and is therefore useful in evaluating adult education with LBMAR games. The players' responses did not change linearly with their age and the

training has had different impact on each age group of learners. Also, statistical analyses proved that training increased the scores of the factors of ARCS model.

Other results of this research showed that those over 36 years old focused more on the facts that the play of “Ingress” is primarily a geographical game and its scenario reflects interesting discussions about the evolution of humanity. Participants in the age groups 20–35 and >52 agreed that the game does not have idle phases, that it combines excitement with insecurity, and that it is pleasant to play locally a game of planetary proportions.Another age-related observation concerned the answers to the question (“How do you feel when you endow the geographical space with personal preferences?”) between age groups with age groups agreeing in pairs: the first two age groups (20–30) and (30–40) agreed more than with the last two (40–50) and (50–60). Yet, in question “Do you think that the game offers opportunities for learning and teaching geography, building on your previous geographical knowledge?” , there was an overlap in the responses of participants among age groups. As for the first question, the most critical concept was: “the users feel a kind of nostalgia”, followed by the concept “the users consider portals as personal creations”. In the case of the second question, the most critical concept was that the participants believe that the game offers entirely new opportunities for education in geography, compared with their previous experiences. This fosters an evidence of constructivist approaches to adult education and, also, relevance of some other prominent theories of adult education such as humanism.

Methodologically, this research it was shown that content analysis is a valuable method for exploring opinions and attitudes of adult users towards MAR games and Jaccard indices can be used to quantitatively explore themes emerging from content analysis. Content analysis was performed on the users’ responses qualitatively in order to identify characteristic sentences expressing attitudes and opinions. For the quantitative assessment of similarities between responses for each question and subconcept, the Jaccard similarity index was calculated pair-wise for every pair of participants. In addition to the Jaccard indices and furthering the scope of new methods for content analysis, this thesis shows how to use Social Network Analysis (SNA) to model concept maps, thus opening up excellent opportunities to create visualizations of concepts and their inter-relationships. Quantitative aspects of SNA analysis (i.e. by using radial centrality and information centrality) provide mechanisms suitable to measure internal relationships in concept maps (in addition to visual inspection) that would not otherwise be visible. Using SNA enabled the classification of users’ responses with respect to their interaction with the game and therefore was a fruitful approach for education that involves MAR games. Furthermore, with this novelty, it is shown how texts derived from interviews or from responses to open questions by different individuals can be analyzed both qualitatively and quantitatively with SNA.

Concluding, this research has produced novelties at both the educational and the methodological levels. As concerns adult education, it was shown that i) LBMAR games are suitable for it, ii) adult education about them can be enhanced by following Keller’s ARCS model, iii) perception and satisfaction of adult learners depends on age, and iv) certain theories of adult education (i.e. constructivism and humanism) can be relevant when adult learners use LBMAR games such as “Ingress”.

As concerns methods of educational research, this research suggested entirely new methods, for first time ever, for analyzing data that are derived from trainees' responses to open questions. These new methods are content analysis of the participants’ responses with the use of Jaccard indices and methods of SNA and can have a wider applicability to educational research.

1. Justification

1. Justification

Augmented Reality (AR) is, no doubt, a fascinating new technology, which has turned out to be particularly useful to education and training, as well as in gaming. As soon as AR became mobile and portable on smartphones, it also became location-enabled. Thus, Location-Based Mobile Augmented Reality Games (LBMARGs) appeared and rapidly became quite popular. The experience of dwelling in (and interacting with) a hybrid world in which the physical blurs with the digital (the virtual) in outdoor environments endows the human mind and senses with entirely new and unprecedented experiences.

As expected, the expansion of a "layer" of digital reality over the physical world uncovered an enormous potential to be explored by game designers. This was promulgated by the introduction of 3G networks of mobile telephony and the embedding of Global Positioning System (GPS) in smartphones (Spallazzo & Mariani, 2018), which resulted in an increasing "gamification" of the Location-Based Mobile Augmented Reality. This technological revolution in gaming has not left the field of education unscathed; in fact, it led to a gamification of education, that involved both entertainment and "serious" games, which, eventually, has pervaded not only education, but also health, business, communication and marketing (Deterding et al. 2011; Zichermann and Cunningham 2011; Werbach and Hunter 2012; Walz and Deterding 2015).

Although the usefulness of LBMARGs to education is increasingly being explored in various contexts, focusing on different aspects of it, i.e. on mobile learning (Sharples et al., 2005) or on the perception of location-based learning experience (Ribeiro et al., 2021), there is still a lot we don't know about how this technological novelty is (or should be) explored for education and training. Moreover, has been widely explored and we already know quite a lot about how youngsters and adolescents perceive, appreciate use this game, we still do not know whether (and to what extent) the same applies to adult users and learners for this kind of games. Also, our knowledge is very poor as to what characteristics of AR, MAR and LBMAR games are more relevant to personal and social contexts of adult education and we do not know how adult users feel, what they appreciate or dislike when they play an LBMAR game.

In as much as the proponents of AR (technologists, educationists, software and hardware industry) aspire to strengthen the position of AR as a platform-technology unifying the digital and the physical worlds in an interesting and engaging way, it is important to explore how adult users perceive, learn and use it. This is because, if not for any other reason, the majority of the population in the developed countries that use this technology consists of adults.

Some decades ago, Malcolm Knowles realized that adult learners want to learn independently, opting for problem-solving and associating what they learn with their previous experiences (Knowles, 1984). As the work of Knowles expanded, several adult learning theories ensued which placed more emphasis on one or another feature of adult learning, and thus appeared remarkable behaviorist, cognitivist, humanistic, and constructivist approaches to adult education. Thus, exploring adult education using AR technologies can be a very complex undertaking, in which may exist links

(depending on each one adult trainee) with the user's/trainee's previous life experiences, personal aims, professional engagements, personal preferences with respect to gaming, as well as links with ideologies, attitudes towards life and society, towards technology. Clearly, these parameters are not encountered in children education.

Evidently, these increase the complexity of educational research with adult learners and, by consequence, they also pose a higher burden on the researcher, since the researcher who works with adult users of AR or LBMAR games is required to delve into this enormous variety of preferences, attitudes, varying skills, expectations and stances that adult trainees may present during such a research project. Consequently, we are led to explore the possible applicability of any new methods that might help us in the analysis of concepts and ideas expressed by adult learners of LBMAR games. As an example, we need to know whether some concepts and ideas mentioned by trainees of such games are reported repeatedly by them and, if it happens, how is it possible to treat quantitatively and qualitatively such occurrences and co-occurrences. As an example, we do not know how to process the verbal expressions of two or more (adult) learners that have mentioned the same concepts or ideas while learning or playing a LBMAR game.

These methodological deficits lead us to explore new avenues in research methods in adult education. Besides, we do not know whether there are any significant age differences among adult players of LBMAR games, to what extent and why, and it is completely unknown whether some central ideas of adult education (i.e. humanism, constructivism) relate to learning LBMAR games by adult users. Furthermore, given that qualitative research offers incomparably more and deeper insights in the educational process in adult education than quantitative research, it clearly should be given precedence, but it is also important to see how results from both types of research can be used to explore how adult users interact with LBMARGs.

All in all, there are two interrelated domains in which this thesis aims to contribute: the LBMARGs-related (how adult learners perceive, evaluate, interact with an LBMAR game) and the methodological (how to explore deeper the complexity of adult learners' concepts and ideas while they learn, use and interact with such a type of games).

2. Introduction

2. Introduction

2.1.AR, MAR, LBMAR Technologies

2.1.1. Augmented Reality (AR)

Augmented Reality (AR) is the "real-time, direct or indirect view of combined physical real-and-world environments that have been enhanced/augmented by adding virtual computer-generated information to it" (Wikipedia). AR technologies are interactive, they make ample use of the 3d (physical and digital) space, by superimposing virtual objects upon the physical reality.

Whereas Virtual Reality (VR) concerns entirely virtual entities that are perceptible only from within the immersion in the "cyberspace", AR mingles cyberspace with physical reality, thus creating an integrated perception of space that is simultaneously physical and virtual. For this reason, Paul Milgram and Fumio Kishino theorized that there is a wide range of possible combinations of real and virtual spaces, in what they named "Reality-Virtuality Continuum" (Milgram & Kishino, 1994),comprising Augmented Reality and Augmented Virtuality (AV) in between, in a manner that AR is closer to the real world and AV is closer to a completely virtual environment.

Endowed with such capabilities, AR is capable of enhancing the users' perception of the real world and the interaction of its users with it (Carmigniani & Furht, 2011). Although VR is essentially a precursor to AR, the key difference between the two is thus the fact that, while VR completely immerses users in a synthetic world, AR augmentsthe sense of reality by superimposing virtual objects and cues upon the real world in real time.

At this point, a disambiguation of terms is due: "cyberspace", as interpreted in the context of VR, is not the Internet; it is simply a completely artificial (electronically-created) environment in which the user is immersed in.

The term Augmented Reality (AR) first appeared in the 1950s when Heilig, a cinematographer, thought of cinema as an activity that would have the ability to draw the viewer into what is shown on the cinema screen, by involving all the human senses in an effective manner. Later (in 1962), he proceeded to built a prototype of his vision, named "Sensorama", which he described in "The Cinema of the Future". This machine essentially predated digital computing. In 1968, Sutherland was the first to create an AR system using an optical head-mounted display (Wagner, 2010). In 1975, Krueger created, for the first time, a room which allowed users to interact with virtual objects, the "Videoplace". Later, Caudell and Mizell from Boeing suggested the term "Augmented Reality", to denote the technology by which workers were aided to assemble wires and cables in that aircraft industry. The first outdoor mobile AR game was "ARQuake", developed by Bruce Thomas in 2000 and demonstrated during the International Symposium on Wearable Computers. In 2005, the influential "Horizon Report" (Johnson et al., 2005) predicted a bright future for AR technologies. Nowadays, with new advances in technology, an increasing amount of AR systems and applications are produced, using MIT's "6^{th} sense" prototype, "Eee Pad" and "iPhone 4", all of which had significantly advanced the use of AR technologies (Carmigniani & Furht, 2011).

The main devices used in AR are displays, input devices, tracking devices, sensors and computers. There are three major types of displays used in Augmented Reality: handheld displays, "Head Mounted Displays" (HMD) and spatial displays. HMD is a display device worn on the head or placed as part of a helmet and presents images of both the real and the virtual environments to the user. HMD can either be video-see-through or optical see-through and they may also comprise a monocular or a binocular display optic device. Handheld displays employ small computing devices with a

display that users can hold in their hands, i.e. using video-see-through techniques to superimpose graphic displays onto the real environment and employ GPS and other computer vision methods: smartphones, PDAs and Tablet PCs (Wagner & Schmalstieg, 2006). The term "Spatial Augmented Reality" (SAR) was suggested to describe the use of (depending on the particular application) holograms, video-projectors, RFID tags and other spatial tracking technologies that enable the display of information directly onto physical objects, which do not require the user to wear or carry the particular display (Bimber & Raskar, 2019). These allow SAR applications to connect groups of users through collaborative schemes and to find applications not only in scientific institutions (e.g. in universities), but also in locations such as museums and establishments related to the arts (Carmignani & Furht, 2011). As for the input devises, these are smartphones, wireless wristbands, as, i.e. in the case of the "ReachMedia AS" (Feldman et al., 2005), gloves (Reitmayr &Schmalstieg,2003) etc. Much of the efficacy and naturalism that an AR system is capable to provide depends on the computational capacity of the devices and the technical characteristics of each particular device. Evidently, these characteristics are meticulously considered while creating the whole AR set up, so that a camera for instance, is compatible with the software (i.e. Android) and the CPU of the computer that runs the whole process.

According to some researchers (Azuma et al., 2001), the HMD (which is widely used in AR), should not be regarded as indispensable or a restrictive characteristic of AR, since AR technologies may also entail all sorts of devices that aim at augmenting hearing, touch, and (although not so often), smell (Carmigniani & Furht, 2011). The potential of these devices for multi-sensory perception has led to creating some specialized AR applications that are suitable for blind users, persons with poor vision, or users with hearing impairments. The applications of these technologies are manifold: in education, marketing, advertising, as aids to carry out practical tasks (i.e. guiding workers by displaying digital information through headsets), entertainment (i.e. by using Wikitude), for carrying out repair operations, for planning robot paths etc. (Carmigniani & Furht, 2011). This is because virtual objects added to the real environment present information to the users that they would not otherwise have been able to detect with their physiological senses in the physical space.

Aside of the usual addition of virtual objects to the physical environment, it is also possible to consider AR applications that require the removal of real objects from their environment, and this has been called "mediated reality" or "diminished reality" (Azuma et al., 2001). Indeed, removing objects from the real world is tantamount to covering an object with virtual information in a way that matches the background in order to give the user the illusion that the object is not there.

2.1.2. Mobile Augmented Reality (MAR)

The "Mobile Augmented Reality" (MAR) technologies achieve the integration of the physical environment with virtual objects within mobile devices. Tracking devices are indispensable to MAR technologies; digital cameras most commonly, in tandem with wireless sensors and solid state compasses (Höllerer & Feiner, 2004; Azuma et al., 2001; Huang et al., 2013). Selecting views and definitions from various researchers (Renevier & Nigay, 2001; Kock, 2010; Azuma et al., 2001; Azuma, 1997; Karimi & Hammad, 2004), it can be concluded that MAR combines real and virtual objects in a real environment, is interactive in real time, registers and aligns real and virtual objects with each other and runs and/or displays augmented views on a mobile device. Any set of hardware and/or software with all these characteristics can be thought of as a MAR system and these capabilities also determine the degree of success of such a system (Papagiannakis et al., 2008).

MAR devices vary from screen smart glasses such as “Google Glasses” or “MadGaze” glasses to holographic displays, such as “Microsoft Hololens”. They may also include smartphones and tablet PCs. Most of these devices employ (or activate) a variety of sensors, enabling them (depending on the particular hardware and software) to perceive location, acceleration and orientation. The hardware capability and the computational capacity of the mobile devices are usually lower than those of a fixed electronic device that is capable of performing comparable computational tasks. But such devices have the in-built capability to connect with remote services and thus obtain access to data that are not stored in the software program that is run by the device (i.e. geographical data), as well as to exploit resources in the cloud (Braud et al., 2017). Besides these, such devices can also work in remote collaboration or to exchange context-aware data. With the advent of cloud computation, some devices are enabled so as to correspond to device-to-cloud technical requirements (Kosta et al., 2012) and to device-to-device communication (Asadi et al., 2014) by exploiting (depending on the MAR application) protocols for device-to-device communication using broadband, 4G, 5G, Bluetooth or WiFi (Braud et al., 2017; Sucipto et al., 2017).

Much like any mobile electronic technology is preferable and gets easier disseminated than its fixed equivalents, so MAR technologies have attracted interest from both academia and industry. In as much as the use of mobile phones is common place and their customary use can quickly get dull to the user, the attractive content offered by MAR can entertain or at least distract users from their everyday use and, in this processes, the intensity and affect offered to the user may even change the user’s perception of mobile phones altogether. Making AR possible on portable mobile platforms such as smartphones has no doubt, been a major breakthrough in the world of mobile telephony. Meanwhile, it appears increasingly feasible that MAR technologies can be adopted to gain access to an even wider range of applications, i.e. by incorporating innovations in human-computer interaction interfaces, computer vision, network caching and cloud computing. These technological developments will eventually lead (Chatzopoulos et al., 2017) to significantly more applications that would be suitable for an extending MAR in tourism, culture and education.

2.1.3. Location-Based Mobile Augmented Reality (LBMAR)

With the introduction of Global Positioning System (GPS) and accelerometers to MAR technologies, mobile devices are upgraded to a level of unprecedented capacity, for they have now become “spatialized”, in the sense that any and all location-based activities are incorporated in the hitherto available capabilities of the devices. Thus, the world of location-based information services has opened avenues leading to the creation of location-based games and location-based ubiquitous learning (Benford et al., 2005; Hwang, 2006; Tan & Chang, 2015).

At this point, a clarification about “GPS” is due: although this term is widely used worldwide, it is essential to notice that the correct term for this technology offering satellite-based location and navigation services is “GNSS” (Global Navigation Satellite System). This is because not all devices that have “GPS” in them always use the GPS data per se. In turn, this is because GPS is the name of the American constellation of satellites, but it the American system is not the only one. The European Union has its own GNSS (“Galileo”), Russia has “Glonass” and China has “Beidu”. However, most chips that are now embedded in the hardware of mobile phones are able to receive signals from more than one GNSS. A test application, named “GPSTest” exists for Android phones, enabling one to test which GNSS is used by a particular phone (and can be downloaded from “Google Store”). This is an open source application, which displays information about the particular GNSS the phone is using in real-time. As a matter of fact, it shows which particular satellites are

positioning data to the particular devise. However, as, imperceptibly perhaps to the user, there are frequent errors of accuracy, signal coverage (availability) and signal continuity from these satellite constellations, the performance of GNSS is enhanced and improved by the "Satellite-Based Augmentation Services" (SBAS). The GPSTest shows the availability of signals from such constellations as well, which have regional or even continental coverage and include the British INMARSAT 3-F2 and INMARSAT 4-F3, the American GALAXY 15, the Canadian ANIK F1, the Japanese QZSS, the Indian GAGAN, the Luxemburgian SES-5 and Astra 5B, the Russian SDCM, the Chinese BDSBAS, the Korean KASS and the Australian SPAN. In European Union in particular, the prominent SBAS is the EGNOS (the European Geostationary Navigation Overlay Service), which covers geographically the entire EU, the Balkans, part of Russia, Turkey and part of West Africa. All these systems are interoperable and mutually compatible, so that not only they don't interfere with one another, but they also provide the user with the same degree of performance regardless of the coverage overlap among the different systems. Without the communication of hand-held or other mobile devices with these satellite constellations, the location-based applications would not have been possible and some LGMAR applications would have been significantly less accurate, if not completely useless.

Expectedly, a prominent field for education research interest is how to best exploit these technologies so as to strengthen the location-awareness functionality of the mobile devices that will further strengthen mobile learning. Besides, in whatever terms and circumstances that is possible or feasible, location-based learning fosters personalized learning, because students or trainees (or the persons that are educated in general) are able to exploit a range of possible applications that relate to their personal position at the moment of using the device through which (and by which) they are trained. In this way, mobile learning becomes adaptive: a location-based adaptive mobile learning, which may also be receptive of contents suited to particular learners according to their location. Hence, by using mobile devices in such a learning process, a context-awareness mobile learning environment is being created (Tan & Chang, 2015).

The first generation of MAR with context-awareness was based on laptops which used location information (Höllerer et al, 1999 and Bauer, et al 2001), but the convergence of context-awareness and MAR has shifted technologies to more lightweight devices such as PDAs, Ultra Mobile Personal Computers (UMPCs), as well as mobile phones (Henrysson & Ollila, 2004). Later, appeared the concept of "ubiquitous learning" (Tan & Chang, 2015), in the sense that particular hardware and software can be used to provide the users with learning and instruction on-demand.

In LBMAR technologies, tracking systems are essential, since they offer ways to identify objects in the physical world. All these systems provide different types of tracking and support location identification. Such systems are (besides the GNSS), the GPRS (Global Positioning Radio Satellite) and UMTS (Universal Mobile Telecommunications System), which also endow mobile phones with the capability to localize within some range from the antennas of the mobile telephony network that has been installed in the user's vicinity (Kalkbrenner & Koppe, 2002).

Also, the use of "markers" has become increasingly popular due to their low cost (Rohs, 2004), but the "marked" objects need to be tagged with codes. Tracking systems by using RFID (Radio Frequency Identification Systems) enables the contact-less reading of the entity that carries the RFID tag within short range distance and contact-less. In a somewhat similar way, the WSN (Wireless Sensors Network) enables the tracking of mobile devices which are connected by means of wireless network cards (Ferscha, 2002).

2.2. AR, MAR, LBMAR Games

2.2.1. AR Games

AR generally offers a synthesis of the physical environment with the world of information, using computer-generated imagery that can be perceived as 3d and the user may interact with it. Besides being widely recognized as the most widespread application of AR technologies, games also bring in contact with new technology and are also suitable for popularizing educational or cultural contexts to very wide publics. For this reason, the computer game, videogame and mobile phone game industries are huge and rapidly expanding, attracting enormous numbers of consumers worldwide (Anderson, 2007).

Whether played on a phone or a board, games can be broadly classified into either entertainment games or serious games. AR games may fall into either of these categories, depending on their purpose and overall setting.

Within the former category of games are the electronic games (playable on computer or mobile phone or on other devices) that have no other apparent aim than to provide entertainment to the player, meaning that the player's enjoyment is the goal that the game was created for (Tan & Soh, 2010). An interesting example of entertainment MAR games that has also been used for research, is the marker-less AR game named "Butterfly Effect" (Norton & MacIntyre, 2005; Tan & Soh, 2010). It is an AR game that uses a rod controller and a HMD. The aim of the game is to capture all virtual "butterflies" that fly in the surrounding 3d space in front of the player, using the rod to attract them and force them to move as a synchronized swarm, in order to catch them. Then, the virtual butterflies are caught by moving the HMD towards them.

The latter category ("serious games") comprises all those games that aim at exercising knowledge or skills of the users, while also offering entertainment, and they thus bring a comprehensive and engaging learning experience to the player that is both educative and entertaining (Zyda, 2005; Stone, 2009). Typical cases of such games are the educational games that are used as teaching aids in schools, advertising games for exploring investment of marketing scenarios for companies and combat games for military simulations. A characteristic example of this category of games is the "Learning Words" (Juan et al., 2010), which is an educational AR game aimed at helping children to learn words. This AR game uses HMDs, cameras and markers and the challenge it poses to children that play with it is to correctly spell out words by placing appropriate markers (user interface menu buttons and video overlay hints) that represent each word at the right place every time.

2.2.2. Mobile Augmented Reality (MAR) Games

MAR games are portable games, which can be downloaded onto one's mobile phone and, as such, they provide unique opportunities for both entertainment and education. The sense of freedom felt by users while playing such games is due to the possibility to move around in space and interact with the world around. This has revolutionized the way games can contribute to education. Further, games are most often associated with emotions and previous life experiences of players (Carmigniani, & Furht, 2011), and, sometimes with particular cultural habits or ideological predispositions. For instance, games involving virtual participation into wars of the past may invoke memories from history books or school education, while games involving shapes and combinations may invoke geometric concepts that the player was taught at school.

Evidently, the context of the term "mobile" has spatial and temporal connotations. Something is "mobile" if it can be moved in space, from one time instance to another.

Yet, what "mobile" is primarily supposed to mean is the ability to take the object away (i.e. the mobile phone) and to use it again at a different location. Thus, the spatial context of a game that is "mobile" is its major and foremost important characteristic. MAR games can be played anytime at any place and this distinguishes them from AR games that are installed at a fixed setting and the player can use them only at a defined location. This clear advantage of MAR games compared to simple AR games has given them a tremendous boost over the last years (Wetzel et al., 2011; Gu & Duh, 2011).

Historically, the first MAR game was "ARQuake" (Piekarski & Thomas, 2002), which was followed by the "Invisible Train" and "AR Soccer". The latter was the first handheld-based AR game that was playable on a smartphone, using computer vision). Next year (Henrysson et al., 2005), a collaborative game was created, the "AR Tennis", which involved the import of ARToolKit to the Symbian platform of mobile phones. Next noteworthy developments in this field included the cooperative mobile AR game named "Art of Defense" (Huynh et al., 2009), the "PIT Strategy"[1], "ARhrrrr Zombies"[2], "Spacecraft Racing"[3], "Marbles"[4] and "Pacman"[5].

2.2.3. Location-Based Mobile AR Games (LBMGs)

Location-Based Mobile Games (LBMGs) are those that exploit the location awareness provided by mobile devices, in tandem with a contextual game experience. Location is hence the major characteristic of these games, in the sense that the play is always associated to a particular location, which is no other than the location of the player (Spallazzo & Mariani, 2018). The game play therefore depends on the location and the game provides significantly different outcomes if it is played at different locations.

However crisp their definition may appear though, LBMGs have sometimes been referred to in the literature by other namings such as "mixed-reality games" (Flintham et al. 2003; Montola, 2011) or "hybrid-reality games" (de Souza e Silva and Delacruz, 2006). These alternative namings essentially have nothing else to offer than shifting the emphasis from the "location-based" (which is the primarily important characteristic of these games) to the usual characteristic of AR games that is the fact that they are playable at the interface of the digital and the physical worlds (while downgrading the fact that the digital content is superimposed on particular locations of the real geographical space). It appears therefore more precise to use the term "LBMG" instead of these other terms.

LBMGs first appeared during the very first years of the 2000s, essentially no much later than the release of GPS-enhanced mobile phones. The precursors of LBMGs are the games "Botfighters" and "Mogi". "Botfighters" was released in 2001 by "It's Alive" and was initially categorized as an urban "Massively Multiplayer Online Role-Playing Game" (MMORPG). That game was revolutionary because, for the first time ever, allowed players to locate other ones within the same city and to engage them in cyber-battles. "Mogi" was released by "Newt Games" in 2003 and allowed its players to use their GPS-enabled phones in order to search for and collect virtual objects that were displayed on the mobile phone, but were dispersed in the physical geographical space. "PacManhattan" was released in 2004 by Frank Lantz and was based on a superimposition of the game board over the streets of Manhattan. It was a "geocaching" game, in which players were trying to catch virtual entities in the real geographical space.

Three technological developments after 2005 brought about a rapid growth in this category of games: the release of Android OS in 2008, the release of iPhone in 2007 and the increase in the size of the screens of mobile phones, also after 2008 (comScore, 2011). All these facilitated LBMG play by boosting both the processing capabilities of the mobile phones and by offering a significantly better gaming experience from using a larger screen. Possibly, these technological developments in

mobile telephony boosted the production of LBMGs like never before, and so a number of such games soon appeared, such as (in alphabetical order): “CityHunters” by “CityHunters”, “Codecrackers” by “La Mosca”, “DarkCity2029” by “Jihad Games”, “Dokobots” by “Dokogeo”, “Gbanga” by “Millform AG”, “Gowalla” by “Gowalla Inc.”, “GPS Mission” by “Orbster”, “Merchant” by “Oberon Interactive BV”, “Monopoly City Streets” by “Tribal DDB” and “Hasbro”. However interesting or fun to play may each one of them be, it is still unknown how successful they have been, to which ages did it appeal most and what advantages or disadvantages there were in each one of them.

No doubt, they have been played by sizeable numbers of people, but they have not been as well known as the real “game-changer” in this category, which was none else than the widely known “Pokémon Go”, which was released in 2016 by “Niantic”- a company that was later absorbed by “Google”. With estimated numbers of over 750 million downloads and $1,2 billions in revenue soon after its release (Apptopia, 2017), this game was (and has been eversince) a class of its own and the most remarkable advancement of LBMGs among youngsters worldwide. The game locates some fictitious creatures called “Pokémons” in the 3d AR space and the player tries to catch them. Although primarily and prominently intended for youngsters, it is hard to conceive that there is anyone who indulges in AR games, or MAR games, or Internet games, or even just desktop computer games and has not ever heard of or has not ever played Pokémon Go. The spectacular success of this game highlighted the charm of LBMGs widely and raised them from the vagueness and obscurity of “mobile phone games” to a remarkable category that deserved special attention, not only by game makers and technologists, but also by educationists, geographers, sociologists, psychologists (Hsiao & Tang, 2021; Saaty et al., 2021; Pamuru et al., 2021; Woods, 2021).

The game “Ingress” is the counterpart of “Pokémon Go”, created by the same company (“Niantic”) in 2012. It was initially launched as a location-based Massively Multiplayer Online Game (Majorek & du Vall, 2016) and became available for Android and iOS. “Ingress” was translated in sixteen languages and its key difference from Pokémon Go is that is intended primarily for adult players.

2.2.4. The Location-Based Mobile AR Game “Ingress”

In “Ingress”, the player has to select membership into one of two opposing factions: either with the “Enlightened” or with the “Resistance”. Locations of historical or cultural significance in a city are marked as “portals” and players strife to conquer them by visiting them in person, holding their mobile phone in their hands and trying to find the “portals” on the digitized map shown on the screens of their mobile phones.

Once captured (as if the users were erecting a flag of their faction at those locations), and if the same players capture more portals in the wider vicinity, they can make firmer the presence of their faction by creating triangles of portals that have been conquered by the same faction. The conquest of a portal may also be challenged by the rival faction, depending on the resources (fictitious “weapons”) that the player uses to defend or conquer a portal. Consequently, wide areas of the city become under the rule of the “Enlightenment” or the “Resistance”. The colors green and blue are used for marking portals and triangles in the AR space of the game.

“Ingress” has an interesting scenario, which, no doubt, is appealing to adult users. The “Enlightenment” faction is related to CERN (the European Centre for Nuclear Research) and aims to impose an “enlightened” rule over humanity. This is opposed by the people of the “Resistance” who opt to discard the agenda of the

"Enlightenment". "Ingress" conforms more with sociological, philosophical and human geographic underpinnings (even though those may be only rudimentary and at some simple level) of the issues normally addressed by adult users rather than by youngsters. For this reason, even though the play of the game can be considered as conformal to the needs of both adult users and adolescents, its scenario is of an entirely different category than that of "Pokémon Go". Possibly, if examined from the point of view of cyber-psychology, "Ingress" might also have served (and still does) as a digital means to express one's ideology in relation to the progress of science in our era and the inevitable problems that are associated with it. Thus, besides being a fascinating game to play, "Ingress" may also serve as a trove for thoughts about alternative futures of humanity, as well as a tool to experiment with in fighting for the type of future one opts for (Shirai et al., 2015; Majorek & Du Vall, 2016; Davis, 2017; Chess, 2014 Hyrynsalmi et al., 2020).

2.3. Adult Education: A theoretical overview

It would not be far from the truth to say that adult education essentially appeared in ancient Athens (4th century b.C.), with the classic approach to learning introduced by the ancient Greek philosopher Socrates and written down by his student Plato. Socrates and Plato used dialogues to discuss various issues, from politics to mathematics, and in this way they tried to make their learners, which were adult learners and mature citizens of the city of Athens, to discover truths by themselves. The Socratic method was called "μαιευτική" and meant the use of one's own experience and logic to discover truths; a method very much reminiscent of modern pedagogical methods (constructivism, experiential learning etc).

In the last centuries however, adult education appeared as a rather late development in the sciences of education and expanded even later. Typically, it appeared in 1833 with the introduction of the term "andragogy" by Alexander Kapp (andra = "man" and agogi = "learning") that was coined to denote rather a mixture of what we nowadays call "adult education" and "continuing education". The term was a composite word, derived from the greek words "andras" (άνδρας=man) and "agogi" (αγωγή=education). Some of the most well known educationists, like John Dewey (1938) and Eduard Lindeman (1926), also tried to advance adult education (still "andragogy" in the first half of the 20th century), but unfortunately, despite the fact that they were well recognized experts in education, their work in "andragogy" was largely ignored (Abela, 2009).

After being nearly absent for almost a century, adult education reemerged in the 1980s with the work of Malcolm Knowles, who organized it and expanded it in the second half of the 20th century (Knowles, 1984). Knowles realized that adult learners prefer independence in their learning, as well as being self-directed, opting for problem-solving utilizing their previous experience and associating what they learn with their daily lives. As the work of Knowles expanded, several adult learning theories ensued which placed more emphasis on one or another feature of adult learning, like situated cognition, self-directed learning, instrumental learning etc (Amstutz, 1999). Although Knowles focused more on the way adults learn than what the impact of teaching is on their learning, it now recognized that motivation given by teachers to adult learners is essential in the learning process (Morrison, 1998). However, it was gradually realized that "andragogy" was more focused on learning rather than teaching. Reflection, for instance, despite being a significant feature of adult learning, was not included in Knowles' model of adult learning (Walker & Harris, 1998; Cantillon et al., 2003). But reflection is a significant indicator of difference between child learning (pedagogy) and adult learning (andragogy), because it has been shown that adult learning is significantly better if taking reflection into account (Chambers & Wall, 2000; Khanchandani, 2001). And, since not all adult

learners are motivated in the same way, it became clear that some deeper, wider and most scrupulous examination of how adult education, teaching and learning are made and how they should be made.

In fact, there are some key differences of child education from adult education. One is the sense of respect: while children are expected to respect their tutors, adult learners are expected to be respected by their tutors. And this goes further into the relationships among adult learners: the basic theory of adult education contends that it is important that they establish respect among themselves. These are prerequisites for establishing a learning environment that is more suited and conducive to adult education (Brookfield, 1986) than they are for child education.

Another difference is the importance of motivation. This is based on two types of theories: "content theories" which explain why adult learners can be motivated, and "process theories" which explain how individuals are motivated (Morrison, 1998).

As for "content theories", Maslow's "Hierarchy of Needs" is probably the most well-known one (Maslow, 1981). The schematic hierarchical tree progresses from the most necessary requirements for one's livelihood such as food and shelter, to the highest which is the achievement of "self-realization". The very basic need in Maslow's hierarchy, which is safety, is thus a necessary precondition for carrying out a successful educational process and, as stated earlier, mutual respect is another psychological precondition for meeting the very basic need of "safety". Following another "content theory", the "ERG" (Morrison et al., 1998), there are three components that enhance motivation: "existence" (similar to Maslow's level bodily well-being and safety), "relatedness" (emphasizing the importance of societal and interpersonal interactions) and "growth" (similar to Maslow's ultimate need for "self-realization").

"Process theories" of motivation are more "behaviorist", focusing more on the fact that certain stimuli create specific behaviors. One characteristic example is the "expectancy theory" (Vroom 1964) that motivation is based on the expectation that a particular result will entail some of the initially anticipated desirable benefits and on the basis of the expectation that the desired outcomes are within the learner's capabilities.

Another feature of adult education is the (almost compulsory) need to take into account the high variety of learning styles of adult learners. This is usually not as important in child education: whereas educating children is almost exclusively a teacher-directed process, in the cause of adult education this is not so. In fact, it is strongly advisable to blend teacher-directed with student-directed learning procedures (Merriam, 2001; Newman & Peile, 2002). This is because adult learners need to express their opinion on the content of learning, and, sometimes also, on the way the educational process develops. It is important for them to make sure that they don't waste their time in a tutorial that they won't have much to take away from, so they inevitably ask themselves whether it was a good decision to attend that course, whether it will be rewarding enough for them and how it could be adjusted to better satisfy their own professional and personal needs.

For these reasons, Jack Mezirow's celebrated theory of "Transformative Learning" of adult education (Mezirow, 1997) aimed at addressing some fundamentals tenets of adult education, particularly by offering a deeper elucidation of how to better handle reflection and motivation in this (more demanding) type of education. Perhaps, the major contribution of Mezirow's theory to adult education has been its effort to address the underlying structures and methods through which adult learners comprehend, assimilate and exploit their previous experiences within a learning process. These reference points are the "frames of reference" that are replete with associated meanings and connotations, which force people to think in some particular ways, to adopt some attitudes and to hold some particular assumptions or stances instead of other ones. Then, Mezirow asked how it would be possible to

reframe those “frames”, by critically reflecting on the underlying assumptions, cognitive and psychological underpinnings. In order to question (and if necessarily topple) previous convictions, transformative learning highlights the tutor’s contribution to aid the learners to question and to reflect on their own (as well as on others’) assumptions. For this to be achieved, it is suggested to educate in small groups, in which experiences that have been accumulated prior to the tutorial would be brought forth and would be reflected upon. Yet, there is still long way to go with Mezirow's theory (Taylor et al., 1997), so it is a research area which appears particularly promising in the future.

A sensational theory in the domain of adult education has been the concept of the “Inner Apprentice” (Neighbour, 1992). Neighbour's theory is strikingly similar to the Platonic-Socratic concept of re-discovery of truth. In Neighbour’s theory, there is an unconscious learning system in humans that is capable of educating itself when it is provided with the correct knowledge and at the right location and time. If found under such favorable circumstances, the “inner apprentice” (the trainee) learns by undergoing stages of “kairos”, that is stages that mark transitions from cognitive dissonance to cognitive resonance. Kairos (καιρός) is a greek word meaning the right time to do something. So a trainee in his/her “kairos” would be able to appreciate the very essence of a problem or issue (or whatever is being taught) and to assimilate learning quicker and deeper. In fact, this mutating experience is strongly reminiscent to what Mezirow aimed at, since, in the congintive resonance process, the incoming information the trainee is fed with goes straight to the “frame of reference” in Mezirow's sense.

However, aside of these theories that have been developed entirely within the domain of adult education, it is necessary to also refer to some theories that are more general in the sciences of education but they nevertheless repeatedly reemerge in researches in adult learning: behaviorism (Skinner, 1974; Smith, 1986), cognitivism (Olson, 2014; Bruner, 1990), humanism (De Carvalho, 1991; Orlov, 1992), and constructivism (Liu & Matthews, 2005; Jones & Brader-Araje, 2002).

Behaviorism contends that learning occurs as a result of environmental stimuli which subsequently provoke certain responses that have an educational effect (Boghossian, 2006). As a learner establishes a complete correspondence between incoming stimuli and desired responses, the learning process succeeds in its aims (Arghode et al., 2017). However, the over-reliance of behaviorists on observable behaviors has led them to downplay the significance of knowledge conceptualization (Foxall, 2008).

Cognitivism focuses on the ways by which the mind stores, processes, analyzes and retrieves information (Yelich Biniecki and Conceicao, 2016; Merriam et al., 2007; Rutherford-Hemming, 2012). As has characteristically been pointed out (McLeod, 2003, p. 38), “a cognitivist sees learning as an internal and active mental process that creates enhanced mental capacity and skills within a learner in order to learn better”. Yet, “cognitivists argue that what is important for adult learners, learning opportunities should allow learners to be actively involved in the process, defining their own goals and activities at times” (Allen, 2007, p. 31). As a consequence, cognitivism is more interested (Yilmaz, 2011; Arghode et al., 2017) in what learners receive as new knowledge and how new knowledge is received by them, rather than what they do with this new knowledge (change of attitudes, “transformative learning” etc).

Humanism, much like the principles of the old andragogy, places more emphasis on the sense of responsibility of the adult learner as a human being: it’s a personal responsibility to advance one’s own learning. Thus, “humanism implies the ultimate objective of learning is to facilitate a self-actualized, autonomous person” (Yang, 2004, p. 138), by aiming straight at the top of Maslow’s hierarchy of needs; at “self-realization” (Maslow, 1943). In doing so, humanist approaches highlight the

importance of self-reliance and self-awareness in the learning process (Milheim, 2011). Echoing the teachings of Socrates, educators are simply the facilitators of the learning process: learners bear the ultimate responsibility of the learning process (Weber, 2014), considering that "the primary goal of humanistic education is to promote personal development and the development of human potential" (Yang, 2004, p. 136). It is noteworthy however, that in adopting this approach to education, humanists give a prevalence of affective factors and emotions over cognitive processes (Merriam et al., 2007; Weber, 2014). From their point of view, these factors not only shape the learning processes but also the course towards self-realization.

Constructivist approaches consider knowledge formation as presupposing both mental effort and involvement of some degree of social engagement in the process (Altman, 2009; Merriam et al., 2007). Learning is accomplished only due to the efforts and the will of learners to acquire the new knowledge to previously gained experiences and to pre-existing concepts (Arghode, 2013; Anderson and Gilmore, 2010; Weibell, 2011; Foote, 2015; Arghode & Wang, 2016). Thus a constructivism-sensitive instruction must take into account the students' desire to learn and assimilate the new knowledge by linking it with previous knowledge, so as to be able not only to comprehend the material, but to conceive it as a "construction", that is something they have "built" themselves upon previously acquired knowledge, experience or skills.

2.4. AR Games in Education

2.4.1. AR and MAR Games in Education

Some of the first applications of AR games had been in the domain of special education. The innovative "GameBook" (Cunha et al., 2016) aided children with ASD to recognize and acquire emotional states by enhancing their attention, motivation and imagination. This game promoted the interaction between the child and the story teller and could be played on any mobile device (i.e. tablet, smartphone). Similarly, another useful to Special Education game was the "Anonyms" (Crepaldi et al., 2017), which was a serious game for enhancing the autonomous management of impulsive behaviors for children that suffer from Attention Deficit Hyperactivity Disorder (ADHD). The game was articulated in separate tasks that enhanced attention and suppressed irrelevant thoughts that frequently arise in children suffering from ADHD. A similar study (Avila-Pesantez et al., 2018) employed research by using AR with the instrument "Kinect", also for children with ADHD. Again, it was shown that the game helped increase attention. With another application, an interesting AR game was used (Kang & Chang, 2020) to gamify skills for using an automated teller machine (ATM) by high school students with special needs. AR games have also been found useful in improving the cognitive development of children with autism (Amado et al., 2021), by helping them to better manage their cognitive tasks.

Yet another example is "Q'inqu" (meaning labyrinth in quechua language); a board game that facilitates the educational inclusion of people with vision impairment (Jadán-Guerrero et al., 2019). It uses cards, a braille code and a board with relief simulating a geographical area and QR codes that provide more information. But it is not only AR games that are useful in special education. The VR component of AR was found particularly beneficial for special education (Sivý et al., 2019). Also, another study (Shaltout et al., 2020) revealed that the use of AR games in education is positively evaluated not only by specialists, but also by parents of children with special needs.

From a classification of learner groups and learning environments of AR games in education (Li et al., 2017), it was shown (after the usual pre-test and post-test analyses of questionnaires and interviews), that the use of AR games presents several advantages for education, of which the most important were the enhancement

of learning, the addition of fun, and enjoyment in education and the arousal of interest. And yet, outside the main field of "educational sciences", in theatre studies, it was shown (Burling, 2013) that students value AR games in education.

But not everything in the garden of AR in education is rosy. Following a study that aimed at examining the positive and negative aspects of using AR videogames in education (Das et al., 2017), it turned out that, despite being very useful in promoting social interaction among children, the immersion and physical movement in AR spaces (that is a prerequisite to play such games), can also present health risks for the players. Nevertheless, the subjects of that study had been children and adolescents (not adult players).

Perhaps following an inverse approach to AR games in education, it was shown that a bottom-up approach to AR game creation for educational purposes may also be beneficial. For instance, creating AR educational games based on students' needs and attitudes and logically progressing towards the educational goals that were to be achieved is also a viable alternative, echoing constructivist approaches (Videnovik et al., 2019).

AR gamification need not be entirely computer-based; it may as well entail board games, card games etc physical objects that can be played without computers, and then build the educational context using AR. Such games have proven useful i.e. in a research (Lin et al., 2020) with health education of high school students, who used a "card-game, slides, and learning-sheets" (CSLS) to create gamification teaching model.

Also, AR games can be combined with classic multimedia, so as to create a unified gamification experience to the learner. One example is the learning platform "mini-games" that is useful for teaching elementary arithmetic operations (Rebollo et al., 2021), in which AR-enhanced videogames help to teach the (otherwise cumbersome and tedious to children) multiplication operation in an enjoyable and attractive fashion.

Furthermore, AR games for educational purposes can be multi-player games, or games that exploit Local Area Network (LAN) connections, as demonstrated, for instance, by an application in medical education (Vidal-Balea et al., 2021). An interesting example (Tzima et al., 2021) of multi-player AR games for education is the serious game "MillSecret", which is useful in learning about the local historical education, as an aid to learn about a characteristic element of local cultural heritage (watermills), which can be played in outdoor settings and enhance the players' experience of local history.

Even from these characteristic examples, it can be seen that each AR game aims at fostering different domains of the players' knowledge (see, i.e. Cazzolla et al., 2019), skills, emotions or attitudes and hence, there are several different criteria by which education with AR games can be evaluated. In a study that presented the evaluation of such games in education for instance (Lin et al., 2020), it was shown that knowledge and learning outcomes varied among participants, as did emotions and states of consciousness during play (i.e. the state of "flow", during which the player is absorbed by playing). Obviously, such evaluation criteria will have to be re-adjusted if one evaluates educational outcomes of an AR game that is played on some mobile platform.

Expectedly, the first thing that comes to mind when the word "mobile" is used is just space; geographical space in particular. Hence, one of the very first studies of educating using MAR games was in geography (Herpich et al., 2018). The research project, in which the subjects had been primary school students, revealed the positive attitudes of students towards it and showed how very appropriate MAR games are for combining theory with practice in geographical education. Yet, in as much as "mobile" means changing (or able to change) place, it also means change of location in time. Such games were found to be useful in teaching not only geography, but also

history, as a case study has shown that referred to women immigrant labor leaders in the early twentieth century (Gottlieb, 2018).

Shifting the emphasis more on educational outcomes than technologies, several questions arise about the deeper psychological and pedagogical implications and correlates of using AR and MAR games in education. Hence, efforts have been made to classify some possible educational contexts relating to the use of such technologies in education (Laine, 2018). Given that it is generally difficult (and, quite often, not feasible at all) to cover all these contexts within a single research study, some authors have focused on particular contexts.

Expectedly, the evaluation of the educational usefulness of a MAR game is primarily affected by its intrinsic technical characteristics, i.e. whether it is marker-less or not. In a study of a marker-less multiplayer game for primary children (López-Faican & Jaen, 2020), it was shown that the game brought about a significant positive increase in communication skills and socialization and fostered their emotional intelligence. And, as the primary aim of that study was to evaluate the role of collaboration among students, it was shown that using a MAR game resulted in increasing dialogue and understanding among participants. However, after examining the "flow" experience for instance for a number of eighth-grade science class students, it was found that gender was related to this kind of experience (Bressler et al., 2019), with girls reporting higher scores in flow. But, as it was shown, the overall educational advantage was not affected by the differences in flow experience. So a MAR game can be very pleasant and very engaging, but being such does not guarantee that it will also be more useful for educational purposes.

2.4.2. Location-Based MAR Games in Education

Probably the first LBMAR game that was widely known and recorded in the literature is the "Environmental detectives" created in 2002 by the MIT Teacher Education Program Eric Klopfer (Klopfer et al., 2002).

Another noteworthy LBMAR game, the "Mystery at the Museum", was created by the same group and it was intended to be used by visitors of the Boston Museum of Science (Klopfer et al. 2005).

The AR game "Reliving the Revolution" (Schrier, 2006) simulated the Battle of Lexington (Massachusetts), allowed players to chose from three different soldier types and thus to interact with virtual historic figures which, if triggered, appeared on the players' PDA, depending on the place each player was located at. With these capabilities, the game offered a significant advancement to situated historical education. Also promoting the historical education related to some place, playing the marker-based LBAR game called "The buildings speak about our city" (Koutromanos & Styliaras, 2015), primary school students are able to explore buildings with historical or architectural value (warehouses) of a city in western Greece. In this game, the students can assume the role of an architect, or a historian or a journalist. Interestingly, the game also represents an example of using LBMAR games to enhance a constructivist approach to learning.

A treasure hunt game using LBMAR games playable in the city of Valetta (Cauchi & Scerri, 2019) is a serious game based on GPS navigation which simultaneously combines tourist information about the city and entertainment.

MAR games can also be used for instructional support, as is the case of the "Mobile Augmented-Reality Game for Instructional Support" (MAGIS), which combines narrative-based game design with player-location tracking (Vidal et al., 2019) and represents a typical such range of applications for location-based historical adventure games. These games provide instructions and game options at the same time and are mainly used for indoors environments, e.g. museums.

Perhaps, one of the best examples of ecological and environmental education using LBMAR games, also suited for urban parks, is the "Edupark" set of apps

(Pombo & Marques, 2019), which contains interdisciplinary educational material suitable for students (10-15 years old) and tutors alike. Its high educational value is demonstrated by the fact that the game enhanced "motivational features, such as treasure hunting, points gathering, the use of mobile devices in nature settings, and AR features to learn" (Pombo & Marques, 2020, p.287). Aside of these advantages however, students also reported they had experienced "difficulties in the use of mobile devices to learn, such as requiring an internet connection, its slowness, not being allowed to use mobile devices in schools as they facilitate access to distractions" (Pombo & Marques, 2019, p.37).

LBMARGs have even been used in business. In a game that appeared early in this category (Puja & Parsons, 2011), and aiming to discover the weaknesses of a company, players assume the role of consultants of a company that exists in the cyberspace. By changing their locations in the physical space and interviewing virtual persons, they can derive recommendations for the company's strategy.

The bulk of research in applications of LBMAR games in education however, concerns the game "Pokémon Go" (Wu, 2019; Hsieh & Chen, 2019; Bagade et al., 2019; Delello et al., 2018).

2.4.3. AR and AR Games in Adult Education

After examining the existing literature on LBMAR games in adult education, it turns out that only few studies have been published in this field, and their results are presented here.

Using "Pokémon Go" has been found to be very useful for teaching students a number of computer science subjects, such as graphics and animation, modeling, networking, GIS and databases (Huang, 2016). Another research that involved Pokémon (Ma et al., 2018) aimed to shed light into the players' physical activity while playing this game. The subjects aged from 13 to 65 years old and it was discovered that the average daily distances walked by the participants increased by 18.1%, therefore suggesting that LBMAR games can also have a significant positive impact on health for both youngsters and adults. In a similar study (Finco et al., 2017) carried out in the city of Pelotas (South of Brazil), using "Pokémon Go" had also shown that users valued this game precisely because it helped them to lead a healthier and more social lifestyle. Further, as the goal in this game is to catch the characteristic doll-resembling figures (the "Pokémons"), its potential has also been exploited in the teaching of wildlife ecology (Lupton, 2017), since catching such a virtual creature resembles catching other creatures in the wilderness of the physical space, thus making this game also suitable for ecological education.

A narrative-driven LBMAR game was proven effective in the case of 42 undergraduates studying English as a foreign language (EFL) in South Korea (Lee, 2020), since it not only enhanced student engagement, but also fostered positive attitudes toward foreign language learning. Curiously though, students preferred its printed version rather than the AR game.

A study that involved university students with a average age 20 years (Borges et al., 2019) aimed at evaluating AR games in nursing, physiotherapy and medicine and concluded with positive evaluations of AR games by the these young adult participants. Also in the field of medical education, a personalized AR training system for teaching anatomy (Ma et al., 2016) uses text information, 3d models of organs and medical imagery, helping the trainees (university students) to learn better the human anatomy; this AR system had, reportedly, an approval rate equal to 91.7%.

Some research results however had mixtures of ages, involving not only adult users but also children. In one of them, a serious game that was suitable for both adults and children, the "Game of the Goose" (Vera et al., 2017) was intended to increase driving safety awareness. In another example, research using a game that was

designed for University students of Civil engineering and high schools has reported positive impact on the learning process (Dinis et al., 2017). Another research in this field (Iguchi et al., 2016) had teachers as its subjects (adult learners). An "Evacuation Instruction Training" system had virtual humans (children who need to be evacuated by teachers and modeled as digital 3d graphics) involved in real-time virtual disaster situations and adults (teachers) having to be trained by using the game in how to lead children to evacuation points.

To this point, it appears that our knowledge with respect to the usefulness and applicability of LBMAR games in adult education significantly lags behind with respect to children education. Considering this deficit, the aims and objectives of the thesis are presented in the following chapter.

2.5. Aims and objectives of this thesis

After examining the hitherto available scientific literature revealed, there are certain domains for which our knowledge is deficient or incomplete, which are the following:

a) As concerns LBMAR games in adult education:

- We know very little as to what are the main characteristics of AR, MAR and LBMAR games that are more relevant to the personal and social contexts of adult education. For instance, why does it matter whether an AR technology is more naturalistic than another and what makes it so?

- Although we know quite a lot about how youngsters and adolescents perceive, appreciate and use LBMAR games (Pokémon Go" mostly), we still do not know whether (and to what extent) the same applies to adult users and learners for this kind of games.

- The globally available, open-access and easy-to-use LBMAR game "Ingress" is very poorly researched, despite the fact that it appears suitable for adult users. Despite its global coverage and its interesting to adult users scenario, it is still almost absent from the peer-reviewed scientific literature.

- We have rather little knowledge about what adult users feel, think, appreciate, dislike, etc when they play an LBMAR game.

- Moreover, our knowledge about how adult users learn to play an LBMAR game is still very poor.

b) As concerns research methods of adult education:

- We do not know if some concepts and ideas mentioned by trainees of such games are reported repeatedly by them and if it happens how is it possible to treat them both quantitatively and qualitatively. We do not know, i.e. how to process the verbal expressions of two or more (adult) learners that have mentioned the same ideas or concepts or sub-concepts while learning or playing a LBMAR game.

- We do not know whether there are any significant age differences among adult players of LBMAR games and to what extent and why.

- We do not know the extent to which some central ideas of adult education such as constructivism relate to playing LBMAR games.

Given these deficiencies in our knowledge and in the literature about LBMAR games and their potential usefulness for adult education, the aim of this thesis is to explore how adult learners of one game of this category assess their experiences about playing with it.

To achieve the aim of this thesis, the thesis addresses this aim in three different contexts: educational, cognitive and methodological. Consequently, the following general research objectives are set out:

- To assess the potential of AR technologies in the personal and social environment of its users:
  - What are the main features of AR that are relevant to learning by using this technology, as suggested by the scientific literature?
  - What is the potential of location-enabled smartphones for education?
- To analyze adult learners' opinions about the LBMAR game "Ingress" both quantitatively and qualitatively;
  - How do some basic factors of motivation of adult learners, such as attention, relevance, confidence and satisfaction, affect their learning?
  - How do theories of adult learning relate with their learning and play of the LBMAR game Ingress?
  - How does age differentiate the opinions of learners with respect to this game?
  - What research methods can be used to analyze the opinions of adult users of the LBMAR game Ingress?

3.Methods

3.Methods

The methods of this thesis were articulated in two main phases: a) bibliographic research, followed by b) empirical research. The latter, in turn, consisted in both quantitative and qualitative research. The main results of this research were reported in four papers (P1, P2, P3, P4) that were published in scientific journals.

3.1. Bibliographic research

The bibliographic research was carried out in order to identify the key characteristics of AR games, their social, psychological and educational contexts and, moreover, to identify the key features of location-based AR games. This research consisted in searching for AR in from EBSCO-host, Scopus and Google Scholar databases, and rendered 29 experimental articles, which were subsequently evaluated further. As it turned out, there are three main axes in LBMAR games: personal, social and technology-related (see P1).The identification of these axes was useful in designing the main axes of the empirical research that followed.

3.2. Empirical Research

The empirical research was based on the training of adult users of Ingress and subsequently recording and analysing (both quantitatively and qualitatively) their views, opinions, ideas and feelings about this LBMAR game. The empirical research consisted in the following stages: a) Training, b) Practice, c) Responding to open and/or closed questions. The results of this empirical research were published in three papers (P2, P3, P4).

Consequently, the three main axes of impacts of LBMAR technologies identified from the first paper that was published within the context of this research correspond to the subsequent three papers (which are focused on education; adult education in particular) as shown in table 3.1.

Table 3.1.
Correspondence of the three main axes of LBMAR technologies (as they were identified in paper P1) with the educational research methods and questions (per number and type) in each paper.

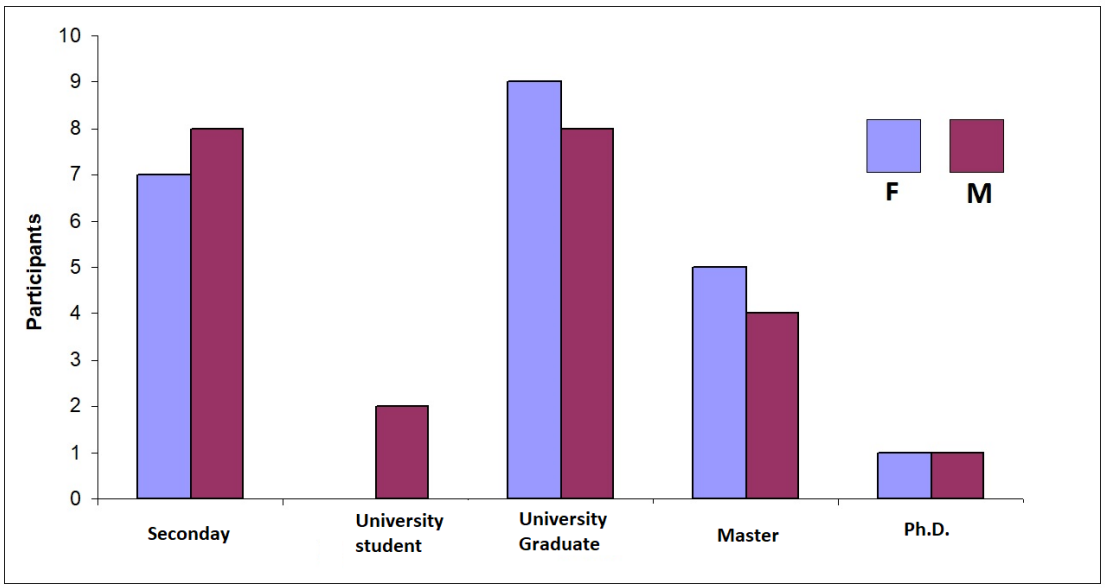
Main axes of Impacts of LBMAR Technologies	**Corresponding Paper**	**Questions**
1. Personal development	P2 (ARCS) P3 (Jaccard) P4 (SNA)	31 closed 5 open 2 open
2. Social environment	P3 (Jaccard)	5 open
3. Use/exploitation of Technology	P2 (ARCS) P3 (Jaccard)	31 closed 5 open

3.2.1. Participants

The group of participants consisted in 45 adult persons, aged 20-60 years old and participated in the years 2019-2021. The sample was not chosen at random in the sense of Goodman & Blum (1996). They came from various socio-economic backgrounds, but they could all understand written and spoken English, were familiar with using smartphones (with Android operating system), and were willing to participate by their own will (upon the invitation extended to them by the author of this research). Twelve out of them had graduated from high school (secondary education), four of them were University students, eighteen University graduates, nine of them were master's degree holders and two of them held doctoral degrees (figure 3.1).

Figure 3.1.

Educational level and sex of all the participants.



3.2.2. Training and Practice

All 45 participants were trained by the author, each one separately, for 2 hours, in the following topics:

a) Introduction to Augmented Reality: brief history of AR, differences with virtual reality, significance for everyday life, for science and technology (30 minutes).
b) Games: why are games important, what "gamification" means and it has to offer in education (10 minutes).
c) Location-based Mobile Augmented Reality Games: Pokemon and Ingress (20 minutes).
d) Ingress: what it is about, rationale of the game, structure, symbols and functions (15 minutes).
e) Ingress: instructions of how to play it in practice (45 minutes).

However, in order to better manage the research project, it was decided that 36 out of the 45 trainees should also be trained for yet another two hours before participating in the research that involved network analysis. This was necessary because, despite that

part of research consisting in only two open questions, providing answers to them required a deeper experience in the use of Ingress. The second phase of training involved the following topics:

a) Presentation of research results about the use of AR (15 minutes)
b) Presentation and discussion of research results about the use of MAR in education (30 minutes)
c) Training in the basic concepts of human geography, urban geography, cultural geography and geospatial technologies (45 minutes)
d) Further discussion of Ingress (30 minutes)

The playtime lasted for minimum one hour for all participants, with an additional two hours duration for those who participated in the second phase of the qualitative research using networks.

3.3. Specific Methods of Analysis

3.3.1. Quantitative Research

All 45 trainees participated in the quantitative research, which consisted in their responding to 31 closed questions accepting only Likert-type answers (1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree). The questions conformed with Keller's ARCS model (Keller, 1983). The ARCS Model of Motivational Design, created by John M. Keller of Florida State University, with hundreds of research studies and applications, can help us understand motivation in teaching (Chang et al., 2020). For motivating guidance, the ARCS Model recognizes four basic strategy factors: «Attention» strategies for arousing and sustaining curiosity and interest, curiosity and interest-arousing-and-maintaining attention tactics. As the instructional design stimulates curiosity and interest in the content or learning background, learners are more inspired. The «Relevance» factor refers to all those techniques that connect to the needs, desires, and motivations of the students. When goals are clearly established and aligned with the needs of learners, they are more driven. The «Confidence» factor examines the techniques that assist students in developing a realistic expectation of success, considering that learners are more inspired when the task is balanced in such a way that the learning process is neither too straightforward nor too challenging for the learner to succeed. Finally, the «Satisfaction» factor of ARCS examines the techniques that reward commitment with both extrinsic and intrinsic rewards, considering that when there are incentives for correctly performed acts, learners are more inspired. Each one of these factors comprises a number of components (not all components apply to all research applications). The aim of the quantitative research was, furthering the findings of the initial bibliographic analysis, to identify which factors of the ARCS model are more affected by age and how much does ARCS model can possibly correspond to adult education (training how to use Ingress in this case).The results were analysed by means of *t*-tests, Pearson's correlation coefficient (*r*) and Cohen's *d* index. The ARCS Model (Keller, 1984) is a strategy for making more motivating instructional material.It has three distinguishing characteristics.First, it has four conceptual categories that encompass many of the concrete concepts and factors that define human motivation.Second, it contains a collection of tactics for improving instruction's motivating appeal.Additionally, it includes a systematic design approach known as "motivating design" (Keller, 1987), which can be used in tandem with traditional instructional models.All of the parameters in the model were based on research findings and practices that have resulted in motivating students;research papers, findings reported in the literature and interviews with instructors were used to create the model (Keller, 1987). Since the gamification of learning aims to increase the user's engagement and motivation during learning sessions by incorporating

games, it has also been made possible by using the ARCS model. (Hamzah et al., 2014).

3.3.2. Qualitative Research

The qualitative research consisted in applying three different (yet compatible) methods of analysis: content analysis, Jaccard indices and Social Network Analysis (SNA). Of the initial group of 45 persons, 24 persons accepted to also participate in qualitative research (after the training session and the play in the field) by responding to 5 open questions. Of them, five were high school graduates, two were university students, eight university graduates, another eight were master's holders and one held a doctorate. Their responses were analysed by means of content analysis and, subsequently, by means of Jaccard indices of agreement. They also participated in the second phase of the qualitative research, but yet another twelve participants participated in the second stage also, thus making 36 participants in total. In the second phase, all participants were trained further into the use of Ingress for two hours more and were allowed to play the game for two more hours. Thus, they gained an in-depth experience of Ingress and were able to respond to the somewhat more difficult questions that were posed to them (two questions) in the second phase. Hence, the empirical research was organized as shown in table 3.2.

Table 3.2.
Educational research methods and questions (per number and type) in each paper.

Phases of the Empirical Research	**Number of Participants**	**Type of Questions**	**Paper number**	**Number of Questions**	**Methods of Analysis**
1. Quantitative	45	Closed	P2	31	Statistics (Descriptive and Inferential)
2. Qualitative - A	24	Open	P3	5	Content Analysis and Jaccard indices
3. Qualitative - B	36	Open	P4	2	Content Analysis and SNA

The Jaccard index of agreement was used to analyse the extent of agreements in users' responses in the first phase of the qualitative research which involved 5 questions. A high cumulative value of the Jaccard index means that more participants referred to a particular concept (or subconcept) in their responses. In this way, it

became possible to identify which concepts were more relevant to the users' understanding and perception of the LBMAR game Ingress.

But the Jaccard index does not identify possible groupings of concepts. For this reason, SNA was used, and with it, the concepts emerging from the responses to two particular answers were "mapped" using networks. The use of SNA aimed to reveal the occurrence and the information centrality of concepts and subconcepts in the "network of concepts and subconcepts". Further, SNA was examined as a tool for conducting educational research in adults.

The statistical methods for treating the quantitative data that resulted from the participants' responses to closed Likert-type questions are standard procedures. The use of content analysis, Jaccard indices and SNA is new for educational research and the methods were also designed so as to examine the possible wider applicability of these novel methods for education and for adult education in particular. Thus, besides the research in adult education about-and-with the specific LBMAR game, the methods adopted for this research were also tested with respect to their efficacy in addressing also other problems arising from educational research.

4. Results

4. Results

4.1. Paper P1

Naturalistic Approaches applied to AR Technology: An Evaluation

Konstantina Sdravopoulou, Juan Jesús Gutiėrrez Castillo, Juan Manuel Muñoz González

Aiming at the exploration of the importance of naturalistic approaches to enhance the user's motivation to use AR technologies, the results, the following main results can be summarized from the analysis of the 33 peer-reviewed published articles:

i) The marker-based AR technologies (which mainly employ camera and visual markers that activate artificial objects, QR codes) were shown to be more appropriative to arouse interest and to facilitate problem-solving in particular knowledge domains and to enhance learners' participation.

ii) The marker-less AR technologies (that uses shape recognition methods) turned out to be more suitable for fostering interactivity, and particularly suited for therapeutic purposes and for exercising visual controls.

iii) The location-based AR (which uses devises such as GPS and accelerometers to detect position and changes in position and links position in the physical space with those in the virtual space). It was proven to be is more suitable for buliding scenarios and it also promotes collaboration.

iv) Naturalistic approaches apply to AR in three different dimensions: in contributing to the personal development of their users, to their interaction with their social environment and these two also relate to the way users exploit this kind of technolog The presence of motion-sensing input devices (i.e. such as those used in location-based AR) facilitates autonomy, problem-solving, and contributes significantly to the stimulation of the user's interest and can also be used to build scenarios.

v) As concerns location-based AR technologies in particular, the use of smartphones accounts for more of the applications of AR (compared to marker-based and markerless types of AR). Further, this type of AR (along with the markerless AR) is encountered in more studies related to human-computer interaction than marker-based AR. These two characteristics, point to a possibly higher relevance to users that would prefer to use smartphones instead of complicated devises and who would interact more with the AR technology.

4.2. Paper P2

Assessment of a Location-based Mobile Augmented Reality Game by Adult Users with the ARCS model

Konstantina Sdravopoulou, Juan Manuel Muñoz Gonzálezand María Dolores Hidalgo-Ariza

Abstract: In mobile augmented reality (MAR) games, learning by doing is important to supplement the theoretical knowledge with practical exercise, in order to maximize the learning outcome. However, in many fields, the users are not able to apply their knowledge in practical ways, despite having achieved a good understanding of the theoretical fundamentals and this is even more important to adult learners. The aim of this research is to examine young, middle-aged and elderly adults' opinion about the location-based MAR game Ingress, by applying John Keller's "ARCS learning motivation model" (Attention, Relevance, Confidence and Satisfaction). The users' responses to closed questions related to Ingress were collected from 45 adult players aged 20-60 from Greece and were subsequently analyzed by means of pre and post quantitative measures of the four ARCS factors. The results show that: a) game training improves all the factors of ARCS, primarily attention and satisfaction b) the responses of young people (20-35) agree more with those of elderly adults (52>) than with those of the intermediate age group of 36-51. Our findings, therefore, highlight the potential and the applicability of the ARCS model in MAR games.

Keywords: Mobile Augmented Reality (MAR), Augmented Reality, Adult Education, MAR Games, ARCS model, Augmented Reality in Education

1. Introduction

Augmented Reality (AR) is a term that refers to the enhancement of the real-life physical world with computer-generated software and hardware that enable the user to function in the real and the virtual space simultaneously.It is also widely acknowledged that AR is real-time interactive and recorded in three dimensions (Azuma, 1997).

Games are widely regarded as the most effective domains of AR applications and are well-known for popularizing modern technologies and the gaming industry is a vast and rapidly growing industry that attracts a large number of customers (Anderson, 2007).As a result, the vast part of the effort put in both AR research and industrial production is centred on game development.

Innovations using mobile technologies have expanded into all market categories over the past few years (Ash, 2015), and their pervasive impact on our activities in urban environments causes a profound shift in culture and practice (Castells, 1996; Fernández-Enríquez & Delgado-Martín, 2020; Bueno et al., 2020). Users are stimulated by augmented reality games to satisfy their needs (De Silva & Sheller, 2014) and location-based mobile games (LBMGs) or hybrid reality games (HRG) are forms of digital games that have arisen as a result of technological advances in both software and hardware. Under the hybrid realities theoretical paradigm, such games use augmented reality as their main technical feature (De Silva & Sheller, 2014; De Roo & Yamu, 2017).The spatiality of digital games has advanced from simplistic two-dimensional worlds to complex three-dimensional worlds (De

Souza e Silva, 2009), and now even to complex (relational) hybrid multi-dimensional spaces (De Souza e Silva & Hjorth, 2009). A hybrid space can be described as a space that exists between the physical and virtual worlds (Winter et al., 2011). The LBMGs are distinguished by their use of embedded GIS and have a profound effect on how people play, communicate and experience a city, by fusing urban and virtual spaces into so-called "hybrid realities" (Colley et al., 2017; Hjorth & Richardson, 2017). These games incorporate player position (which is transmitted via GPS signals) into the gameplay, as well as the user's speed, heading, and orientation (Paras & Bizzocchi, 2005). The geographical location of a player's avatar in the map-based virtual world corresponds to a precise physical location, allowing for unique interaction possibilities b using the player's mobile phone.

Game environments have a high potential for facilitating immersive learning. The act, method, or experience of acquiring information or ability to play the game is referred to as "learning". Learners need encouragement to participate in the act of learning information or abilities (Chan & Ahern, 1999) and adult learners probably more so. According to Chan and Ahern (1999), when people are fundamentally inspired to learn, they not only learn more, but they also have a more positive experience.

To inspire a potential user of one of such AR games means to "offer an opportunity" and the tutor must give them a reason to participate in the process of learning (Chan & Ahern, 1999). Motivation is often considered a preliminary phase in the instructional process in conventional instructional design practice (Small, 1997). Although such a practice usually focuses on a less integrated approach, the aim of education has always been to cultivate life-long learners who are intrinsically motivated, exhibit intellectual curiosity, enjoy learning, and continue pursuing information after their formal instruction has ended (Keller, 1983).

The sum of effort spent during the learning process can be used to determine whether or not the students were motivated. However, in order for 'effort' to take place, two conditions must be met (Chan & Ahern, 1999): the task must be valuable to the individual and the person must believe they can complete the task successfully. In any given instructional scenario, the learning assignment must be delivered in a way that is both stimulating and meaningful to the student, as well as one that fosters constructive expectations for meeting learning objectives (Keller, 1983).The ARCS Model of Motivational Design, created by John M. Keller of Florida State University, with hundreds of researches and applications can help us understand motivation in teaching (Chang et al., 2020). For motivating guidance, the ARCS Model recognizes four basic strategy factors: «*Attention»* strategies for arousing and sustaining curiosity and interest, curiosity and interest-arousing-and-maintaining attention tactics. As the instructional design stimulates curiosity and interest in the content or learning background, learners are more inspired. The «*Relevance»* factor refers to all those techniques that connect to the needs, desires, and motivations of the students. When goals are clearly established and aligned with the needs of learners, they are more driven. The «*Confidence»* factor examines the techniques that assist students in developing a realistic expectation of success, considering that learners are more inspired when the task is balanced in such a way that the learning process is neither too straightforward nor too challenging for the learner to succeed. Finally, the «*Satisfaction»* factor of ARCS examines the techniques that reward commitment with both extrinsic and intrinsic rewards, considering that when there are incentives for correctly performed acts, learners are more inspired. Each one of these factors comprises a number of components. (not all components apply to all research applications).

Chang et al. (2020) presented a mobile augmented reality (MAR) application supporting teaching activities in interior design. Lin et al. (2021) studied a board game assimilating AR into health education and they found that learning motivation

was improved by the integration of AR into the health education board game. Kaur et al. (2020) studied the use of Augmented Reality as a tool for interactive learning in various fields of engineering education and its contribution towards student motivation in classroom scenarios with the ARCS model. Hamzah et al. (2014) proposed an enhanced ARCS model for gamification of learning called “ARCS + G”. Schmidt (2007), Di Serio et al. (2013), Gómez-Galán et al. (2020) and Gutierrez & Fernandez (2014) suggested the utilization of Augmented Reality for enhancing student motivation by improving the visualization of course material for better understanding. However, how adult users assess mobile augmented reality games with ARCS model has hitherto never been examined or explored, and neither learning how to play location-based MAR games has been examined in terms of the ARCS framework. This research uses the MAR game “Ingress”, which was developed and published by “Niantic” (one of the spinoff companies of “Google”), in 2014.The company was the same that created yet another very popular MAR game, the “Pokémon Go”, but while the latter is intentended mainly for youngsters, “Ingress” can be played by adult players also.

The key concept of “Ingress” is that there are two factions of players: the “Enlightenment”and the “Resistance” and players need to choose only one of them to identify themselves with. Both factions need to expand their influence in the virtual space and this is achieved conquering in the virtual space specific locations of the real space named "portals" that are dispersed in various locations,mainly in urban areas (Karpashevich et al., 2016).

By locating a marker called “resonator”at a portal, users can leave a personal mark (through their mobile phone) in the game’s virtual space on behalf of their faction and so the portal changes colour to either green for the faction of “Enlightened” ones or blue for the “Resistance”. If players come across portals that they have already been conquered by the opposite team, they can displace the opponents by using virtual “weaponry” provided by the system. As the ultimate aim of each one of the two virtual factions is to expand their influence in virtual space (by conquering portals), a further procedure provided by the game is to connect portals so as to create triangles, which, in turn, define “fields” and thus establish a stronger control in space for the faction that has created them.

Thus, this study addresses these research gaps by concentrating on the following research issues: Based on the ARCS model, how do adult learners assess a location-based MAR game? Which factors of the ARCS model affect more the training in location-based MAR games?

2. Materials and Methods

To achieve the aim and objectives of the project, quantitative research methods were applied for data collection in order to assess the educational activity that was carried out and was focused on the location-based MAR game Ingress. With the training session,participants familiarized themselves withthe game menu, learned to follow the vocal instructions, to recognize symbols and icons of the game and learned the game’s (most commonly used) procedures (selecting weapons, recognizing triangles, conquering portals, etc).

The educational research project involved 45 users in Greece, aged 20 to 60 years old. The participants were chosen on the basis of four characteristics: a) they had been using an Android smartphone already, b) they understood written and spoken English, c) they could understand written or oral instructions the game provides them and d) they were not familiar with Ingress at all. Of the participants, 12 were graduates of secondary education, 4 University students, 18 University graduates, 9 held a master's degree and 2 held a doctoral degree. The participants were divided into three age groups: 20-35, 36-51 and >52 (table 4.2.1) with 15

persons per age group and they were trained to learn the basics of Ingress for two hours and then played Ingress for about one hour.

Table 1
Statistical description of participant age groups.

Age group	20-35	36-51	52-60	20-60
n	15	15	15	45
mean	28,6	44,4	56	43
s.d.	4,71	4,54	2,14	11,93
median	30	44	56	44

Before and after playing the game, a questionnaire-based survey was conducted using the ARCS model to find out the level of learners' motivation in relation to the parameters measuring attention (A), relevance (R), confidence (C) and satisfaction (S) of the participants for playing Ingress. The survey questionnaire was composed of 31 closed questions, and was developed specifically for this research, allowing for answers based on a 5-point Likert scale (with 1 being strong disagreement and 5 strong agreement). Each question corresponds to a certain category of Keller's ARCS model as shown in table 2.

Table 2
Questionnaire to investigate participant motivation with MAR game (Ingress), and correspondence of each question to Keller's motivation components in the ARCS model.

No	No.	Question	Keller's Motivation Component
1	A_1	The application contributes to sharpening decision making and problem-solving skills.	A.5.2
2	A_2	Your attention was attracted already at the beginning of the game.	A.2.1
3	A_3	You feel "immersed" while playing the game.	A.6.1
4	A_4	The visual characteristics of the application are attractive to you.	A.3.3
5	A_5	The user interface of the application is efficient.	A.5.3
6	A_6	The visual complexity of the shapes shown by the game affects the learning process.	A.5.1
7	A_7	The range of colors shown by the game affects the learning process.	A.5.1
8	A_8	The ordering and sequencing of shapes, forms and sounds of the game affects the learning process.	A.5.1
9	R_1	The application allows you to develop friendly interactions with other users	R.4.2
10	R_2	The contents of the game are relevant to your interests and everyday life.	R.1.3
11	R_3	You would prefer to get acquainted with AR with the aid of this particular game instead of any other application.	R.3.1
12	R_4	The particular game is suitable to teach AR.	R.5.3
13	R_5	The software allows you to take a break and continue later.	R.5.2
14	R_6	The game relates to your own future goals.	R.3.2
15	R_7	The application offers a combination of your mental and physical skills.	R.1.1
16	R_8	You intend to recommend the application to others.	R.3.2
17	C_1	You use correct terms while referring to the application.	C.1.1

18	C_2	You have the impression (at first sight) that this would be an easy game to play.	C.3.1
19	C_3	The application presents surprises.	C.2.1
20	C_4	The game presents new challenges at the right pace.	C.2.1
21	C_5	The game contributed to you some concepts of geography.	C.3.2
22	C_6	The application is simple to use.	C.5.3
23	C_7	The instructions to the user are properly written/expressed.	C.1.1
24	C_8	The application can quickly be learnt by the user.	C.3.2
25	S_1	The procedures of the application motivate the user.	S.3.4
26	S_2	The application is entertaining to the user.	S.5.1
27	S_3	The application presents adequate reinforcements.	S.5.3
28	S_4	The user is rewarded by a sense of accomplishment when winning the game.	S.2.1
29	S_5	The user feels satisfied from playing the game.	S.1.1
30	S_6	The application enhances the user's skills during the game.	S.5.1
31	S_7	The use of AR made the user feel uneasiness, anxiety or other discomfort.	S.4.1

Data analysis employed quantitative approaches. The purpose of the quantitative data analysis was to measure how training of the game effects participants' learning motivation across the ARCS factors. To better visualize the relationships among statistical means and standard deviations by ARCS factor, by age, standard deviation balls were used. The radius of each ball is equal to the standard deviation.

3. Results

The questionnaire was designed with 31 items with an acceptable reliability score of 0.97 (Cronbach alpha).

The mean value of participants' responses per question for each one of the A,R,C,S factors was calculated by dividing the sum of the Likert scores (ranging from 1 to 5) for each question by the total number of participants (table 3 and figure 1).

Table 3.

Standard deviations of the participants' answers per ARCS factor and per question of the ARCS model, before training (b.t.) and after training (a.t.)

	A				R				C				S			
Question number	b.t.		a.t.		b.t.		a.t.		b.t.		a.t.		b.t.		a.t.	
	M	sd	M	sd	M	sd	M	sd	M	sd	M	sd	M	sd	M	sd
1	2.04	0.63	3.04	1.15	2.78	0.51	3.53	0.91	3.09	0.55	3.64	0.76	2.49	0.69	3.33	0.7
2	2.27	0.57	3.89	1.02	2.4	0.74	2.62	0.97	2.89	0.85	3.58	0.83	2.73	0.44	3.93	0.44
3	2.20	0.58	3.29	0.98	2.38	0.79	2.58	0.86	2.56	0.83	2.96	0.92	2.38	0.71	3.27	0.72
4	2.36	0.60	3.53	0.96	3.38	0.64	4.00	0.52	2.60	0.88	3.00	0.92	2.18	0.64	3.07	0.88
5	2.47	0.65	3.62	0.74	3.24	0.73	3.87	0.72	3.42	0.58	4.22	0.42	2.71	0.45	4.09	0.51
6	2.22	0.63	3.36	1.08	2.33	0.89	2.58	1.02	3.13	0.72	3.89	0.67	2.42	0.65	3.36	1.00
7	2.24	0.64	3.35	1.76	3.47	0.62	4.2	0.58	2.82	0.74	3.22	0.87	1.93	0.95	1.93	0.90
8	2.24	0.63	3.31	1.15	3.25	0.63	3.91	0.81	3.00	0.67	3.69	0.69	-	-	-	-

Figure 1

*Average mean score and standard deviation of responses by all participants for the 31 questions per factor of the ARCS model, before training (lower row) and after training (upper row) per age group (ball sizes are proportional to standard deviation): Attention (**a**), Relevance (**b**),Confidence (**c**), Satisfaction (**d**).*

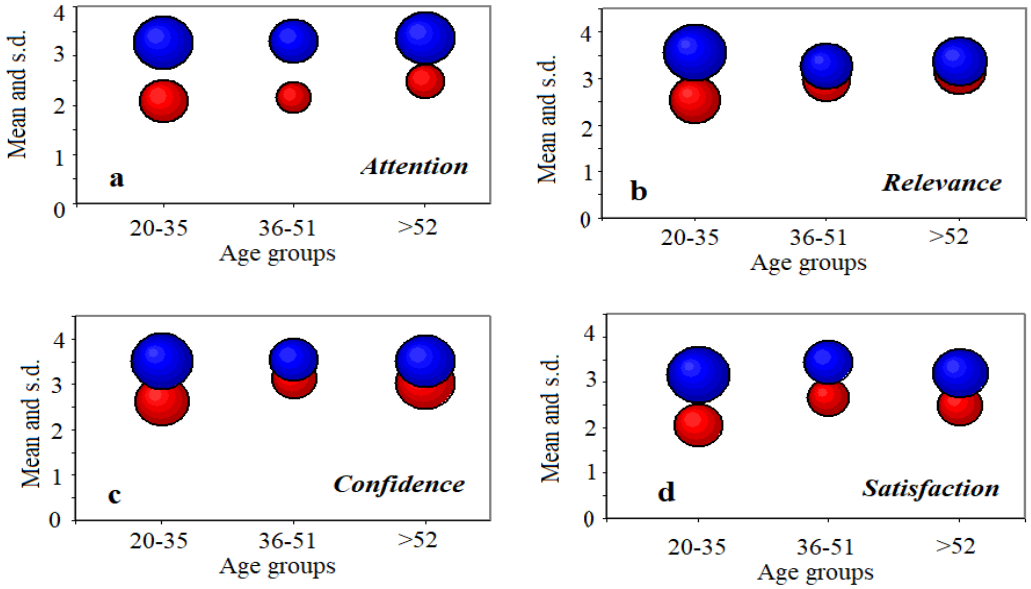


Figure 1a shows the average mean score (on the Likert scale) and the standard deviation of all participants for the eight questions that belong to the Attention factor, before training (lower row) and after training (upper row) with the diameter of each ball being proportional to the standard deviation. The factor of Attention improved for all the questions after training in the game. Additionally, the standard deviation of the answers is higher after game training, indicating that there was greater heterogeneity and variability in the values of participants' answers after training. These results show that participants were highly satisfied with the training of the game. The largest statistically significant difference observed in the questions contained in the factor of attention was between the age groups 20-35 and 52-60 (the test-statistic was -2.4879, with *P*-value 0.006306, which was statistically significant ($p<0.01$).

In questions R_1, R_2, R_3, and R_6 answers before and after training are highly similar, while in questions R_4, R_5, R_7, R_8, they are less so (figure 1b). Considering also that there is no noticeable difference in the standard deviation of the answers before and after the game training, it follows that the training did not affect participants significantly in terms of Relevance of the ARCS model.

Further, from the responses to questions C_1, C_3, C_4, and C_7, it can be seen (figure 1c) that there is a great overlap of answers before and after training while in questions C_2, C_5, C_6, C_8, there is less overlap of participant answers. Additionally, as the standard deviation of question C_5 is smaller there was smaller heterogeneity and variability in the values of participants' answers after the training. These results show that training did not affect participants in terms of the factor of Confidence from the ARCS model.

Figure 1d shows the average mean score and the standard deviation of all participants for the seven questions that belong to the category of satisfaction before training (lower row) and after training (upper row). We can see that the factor of

satisfaction was improved for all the questions after the game training. Also, the standard deviation of the answers is about the same after training of the game. These results indicate participants were highly satisfied with the training of the game pointing to the fact that training improved their "satisfaction" in the ARCS model. The largest statistically significant difference observed in the questions contained in the factor of satisfaction was between the age groups 20-35 and 36-51 (test statistic – 1.90892, with*P*-value 0.01956, which was statistically significant at the level of statistical significance $p<0.05$).

The response from the post-test feedback shows that there were high levels of motivation in terms of Attention (A) with mean score 3.42, Relevance (R) with mean score 3.41, Confidence (C) with mean score 3.52 and Satisfaction (S) with mean score 3.28.

Concerning all four factors of the ARCS model, we see that responses to questions A_5, R_7, C_5 and S_2 yielded the highest differences before and after game training.

An interesting picture is revealed with respect to age differences (table 4, figure 1). The scores for the factor of Attention were higher for the age groups 20-35 and 36-51 after the training session, so the participants' Attention (as measured by questions corresponding to the ARCS model) improved after the training. As for the factor of Relevance, higher scores were reported for the age group 20-35 after training, as were for the factor of Confidence (while in the other age groups there was an overlap of the answers before and after the game training of the factor Confidence). However, the factor of Satisfaction improved after training for all age groups. The statistical comparisons among age groups and ARCS factors were carried out by means of *t*-test.

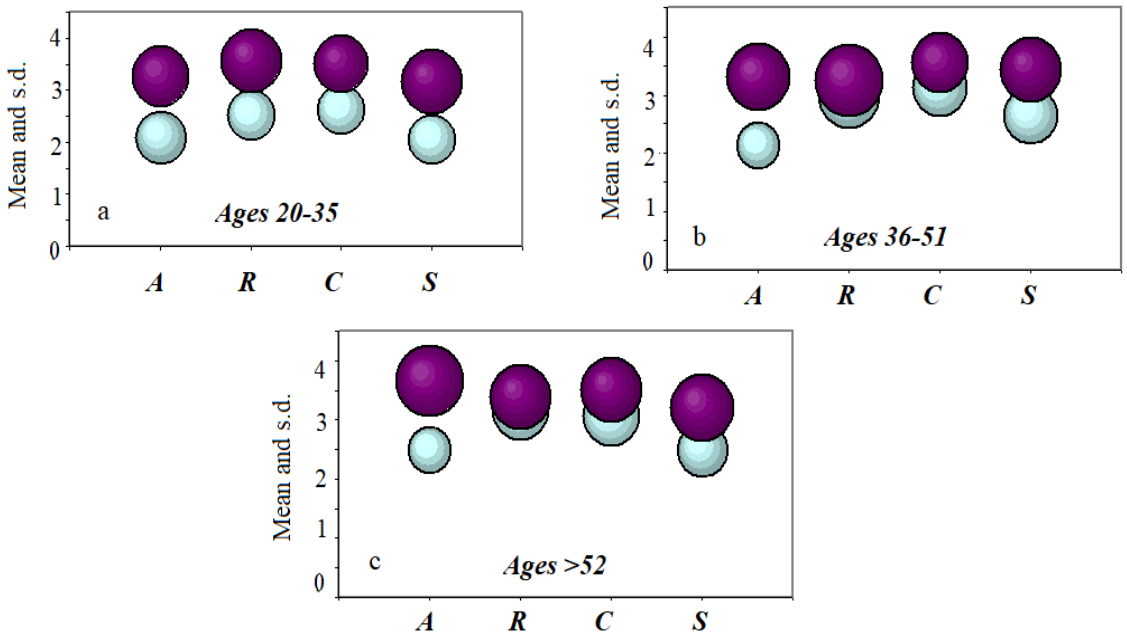
From figure 2a, it follows that scores for all ARCS factors improved after training. Additionally, the standard deviations are all greater after the training of the game, which means higher heterogeneity in the assessments after training. Also, the participants of age group 20-35 were highly satisfied with the training of the game by reporting that training improved their Attention, Relevance, Confidence and Satisfaction. The highest statistically significant differences were observed in the age group 20-35 and were between Attention and Confidence (test statistic: -1.6478, *P*-value=0.0497, $p<0.05$) and between Attention and Relevance (test statistic: -1.82747, *P*-value=0.03636, $p<0.05$).

Table 4

Standard deviations of the participants' answers per ARCS factor and per age group, before training (b.t.) and after training (a.t.)

	A		R		C		S	
Age group	b.t.	a.t.	b.t.	a.t.	b.t.	a.t.	b.t.	a.t.
20-35	0.82	1.18	0.79	1.23	0.78	1.02	0.74	1.19
36-51	0.39	0.83	0.73	0.88	0.56	0.66	0.58	0.70
3>52	0.52	1.16	0.86	0.98	0.88	0.91	0.68	1.02

Figure 2
Mean score and the standard deviations per age group, for all questions, for the factors of Attention (A), Relevance (R), Confidence (C) and Satisfaction (S) of the ARCS model, before training (lower row) and after training (upper row).



*Note: The diameter of each ball is proportional to the standard deviation: 20-35 (**a**), 36-51 (**b**), >52 (**c**).*

Figure 2b displays how the factors of Attention and Satisfaction improved after training, while there was an overlap of scores related to the factors of Relevance and Confidence after training. Additionally, the standard deviation is greater after the training for the factors of Attention and Satisfaction. These results indicate that the participants of age group 36-51 were highly satisfied with the training of the game by agreeing to the fact that training improved their Attention and Satisfaction, while the factors of Relevance and Confidence remained relatively unaffected. The highest differences were observed in the age group 36-51 were between Attention - Confidence (test statistic: -2.43016, *P*-value=0.007546, $p<0.05$), between Attention and Relevance (test statistic: -0.453267, with *P*-value=0.6618, $p<0.05$) and between Relevance and Satisfaction (test statistic: -1.75794, *P*-value=0,03975, $p<0.05$).

From figure 2c it follows that the scores for the factors Attention and Satisfaction also improved after training, while there was similarity of responses to the factors of Relevance and Confidence after the training of the game. It also follows that the participants of age group >52 were highly satisfied with the training of the game by agreeing to the fact that training raised their Attention and Satisfaction scores, while the factors of Relevance and Confidence remained relatively stable.

The correlation among the ARCS factors was calculated before and after training with the Pearson *r* index (table 5): the lowest correlation and the least significant one was for Attention, meaning that the highest impact made by training was for the factor Attention, while the impact of training was least significant in the factors of Confidence and Relevance.

Table 5
Pearson r for ARCS before and after training for each factor of the ARCS model (Attention, Relevance, Confidence, Satisfaction).

	Pearson *r*	*P*-value	Significant at
A	0.7064	0.050157	$p<0.10$
R	0.9841	0.00001	$p<0.01$
C	0.9784	0.000025	$p<0.01$
S	0.8399	0.018036	$p<0.05$

The effect of training per ARCS factor and per age group was calculated by means of Cohen's *d* effect measure (Cohen, 1988) and its interpretation by Sawilowsky (2009) as shown in table 6.

Table 6
Values of Cohen's d measure of effect, per ARCS factor and per age group: the highest effect of training was for the age 20-35 and, for all ages, for the factors A and S.

	ARCS factors			
	A	R	C	S
Age groups				
20-35	1.183	1.007	1.005	1.174
36-51	1.365	0.363	0.685	1.219
52-60	1.047	0.233	0.511	0.847

4. Discussion

The ARCS model provides a useful method for diagnosing students' motivational issues and educational results, and is particularly suited for research with adult learners. Researchers may recognize key motivational problems and understand how these evolve over time by comparing pre-and-post training outcomes. Additionally, researchers can look at the interactions between all four ARCS factors and decide how they can improve the guidance and their instruction to achieve the desired motivational outcome (Huang et al., 2004). Interpreting ARCS findings can be difficult due to the complexities involved in learning motivation, since several variables must be considered while carrying out research in learning motivation and the reverse: no single cause results in a motivational problem.Consequently, when it comes to diagnosing motivational problems, researchers must take an eclectic approach (Huang et al., 2004).

Studies indicate that the ARCS model may be well adopted to computer-based or web-based instructional environment (Keller, 1995), although it was originally designed for developing motivating instructional materials in traditional instructional

settings (face-to-face, classroom-based). Several concepts about learning motivation are incorporated into the ARCS model, butthe central idea is to include a well-systematized approach to instructional and learning designs.As a result, teaching materials are more in line with participatory learning designs and provide interactivity to motivate students and this makes the ARCS model particularly attractive to carry out research with adult learners. The design of teaching material is a major factor in attracting students' attention and keeping them engaged in the learning process.Learning results could be unsatisfactory if students are not paying attention and are not interested in the learning material or methods (Chang et al., 2020).

Our study had some limitations. First, we conducted this research with people who had never played a mobile AR game before. In other words, variations in constructs were discovered among non-users but not among users and hence, future research into the factors that drive general interest in these games is still required. Second, it's likely that some of the results of this study are skewed by the study's spatial settings (i.e. cityscapes within the same city) or the demographics of the participants, pointing to the need for further studies, under different conditions and with different participants. Third, different findings might be obtained if the three age groups were classified differently. Fourth, restrictions in the number of participants per age group may affect the research finding that the age group 20-35 has more similarities with the age group >52.

This research highlighted the effects of integrating the ARCS model into the learning phase of a MAR game and the influence of this new implementation model on participants' motivation. Specifically, it is shown here that:

i) Using the ARCS model enabled the classification of users' responses with respect to their interaction with the game and was therefore useful for education with MAR game.

ii) The players' responses did not change linearly with their age.

iii) The training has had different impact on each age group of learners.

iv) The training increased the scores of the factors of ARCS model.

v) Our statistical results verified that teaching a MAR game to adults has had a positive effect on ARCS factors of their attitudes and perceptions of the game Ingress and, finally,

vi) While Keller's motivational instructional design ideas can indeed be applicable to emerging interactive learning platforms such as MAR , our research presented evidence that Keller's framework can be coupled with the use of cutting-edge digital technology in outdoors education.

Ingress combines a powerful collection of creative mechanisms based on a wide variety of LBMG possibilities.Its hybrid spatiality, which colocates material and virtual elements in the city, blurs the game space and the space of urban activities, causing them to become intertwined and entangled, as de Souza e Silva (2009) and Montola (2005) suggested.The city is viewed through a dynamic "digital skin" (Rabari & Storper, 2015), which generates (re)readings of territory and related activities.The opportunity for players to suggest game elements and have them supported by providing knowledge about physical spaces in the city creates a bottom-up mechanism for Volunteered Geographic Information (VGI) (Goodchild, 2007)that involves players who try to re-define the geographical information available over the game board.The flow of knowledge between the digital and physical worlds is gradually aligning them, blurring the lines and incorporating them into a hybridized space.This aids in city exploration and discovery by providing players with new and additional knowledge about known and unknown locations (Sengupta et al., 2020).The tools for player communication and cooperation open up a whole new world of strategic and spatial possibilities for engaging with fellow citizens.Ingress

“interlaces” with urban life in various ways (Fragoso & Reis, 2016) and, due to its pervasiveness, users may play it in between other activities unrelated to the game (shopping, promenading etc). Indeed, the game can be played on the spur of the moment, depending on the player's position in the city and the need to respond to changing game conditions.

Previous research has found that younger adults (18–35 years) are more comfortable with videogames than older ones (Malik et al., 2016; Malik et al., 2019; Taddicken, 2014; Peleg-Adler et al., 2018). In contrast, Madrigal-Pana et al. (2019) suggested that game exposure and practice rather than age, may be the causes of any negative attitudes toward games.Additionally, recent research indicates that once older adults understand and play videogames, their negative attitudes begin to fade (Ivory & Kalyanaraman, 2009; Ferguson & Donnellan, 2017). In contrast to these findings, our research with Ingress research shows that the adult users of the 52> age group can have a positive attitude toward it. Indeed, Przybylski's (2014) study, which found a connection between negative attitudes toward video games and generational issues, backs this up. Evidence also suggests that older adults now embrace and use technology, and that their acceptance and use is influenced by their personality, behavior, education, income, and age, among other things (Vroman et al., 2015; Hargittai & Dobransky, 2017). In conclusion, although age has consistently been found to be an indicator of negative attitudes toward videogame use in the general population and among academics (Ferguson & Donnellan, 2017; Przybylski, 2014; Ferguson & Colwell, 2017), once older adults understand the material and play the videogames, they no longer report negative attitudes (Ferguson & Donnellan, 2017). This supports the argument that, at least in part, concerns about such games may stem from a general ignorance about this kind of games.

5. Conclusions

Keller (1987) emphasized that the application of ARCS motivation model A, R, C, S four factors are interlinked, and the positive direction of each link will definitely make the student’s learning a virtuous circle. This is of particular relevance for users of MAR games, as they need to be aware about the rules of the specific game. Thus, training in the game before play endows users is a worthwhile effort.

This study revealed that the ARCS motivation model can provide users of MAR games with design strategies for identifying and understanding their motivational needs to promote learning motivation and effectively improve user learning and performance. Our results demonstrated the applicability of the ARCS model in MAR games, that goes beyond the range of its hitherto known applications: ARCS can be a useful model for evaluating education with Augmented Reality (AR).

By applying pre-and post- quantitative measures of the four ARCS factors for the users' responses to closed questions related to Ingress, it was found that game training improved all the factors of ARCS and primarily “attention” and “satisfaction”. It was also found that the responses of young people agreed more with those of elderly adults than with those of the intermediate age group. Also, we found that training affected positively all the domains of participants’ involvement in terms of user learning, user engagement, user behavior and user feedback.

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4.3. Paper P3

Educating Adults with a Location-Based Augmented Reality Game: A Content Analysis Approach

Konstantina Sdravopoulou*, Juan Manuel Muñoz González and María Dolores Hidalgo-Ariza

Abstract: With the exception of Pokémon Go, relatively little is known about other Mobile Augmented Reality (MAR) games, and the attitudes of middle-aged and elderly adults towards them are hitherto poorly examined. The aim of this research is to examine the opinions of young, middle-aged, and elderly adults about the location-based MAR game Ingress. The responses to questions related to Ingress were collected from 24 adult players aged 20–60 from Greece and subsequently were analyzed by means of content analysis, both qualitatively and quantitatively, using the Jaccard index of similarity. Our findings showed that opinions of young people (20–35) agree more with those of elderly adults (>52) than with those of the intermediate age group of 36–51. It was also revealed that knowledge of geography facilitates the ability to play the game better, the game's scenario is very interesting to adults, and the feeling of playing locally in a global game is also appreciated by all age groups. Along with these findings, with this research, it was shown that (a) content analysis is a valuable method for exploring opinions and attitudes of adult users towards MAR games and (b) Jaccard indices can be used to quantitatively explore themes emerging from content analysis.

Keywords: mobile augmented reality (MAR), augmented reality; adult education; MAR games, content analysis, Jaccard index, Ingress, augmented reality in education

1. Introduction

Innovations using mobile technologies have expanded into all market categories over the past few years (Salehan & Negahban, 2013; Fernández-Enríquez & Delgado-Martín, 2020), and augmented reality (AR) applications for mobile devices have dynamically entered the consumer market (Cabero-Almenara & Roig-Vila, 2019). In addition, innovations have converged from devices used for personal tasks (e.g., a mobile phone can be used to make phone calls and to serve as a digital assistant) to devices that can be used for a broad range of tasks (Velázquez & Méndez, 2021).

AR is the name of a media type in which digital knowledge is realistically incorporated into the physical world, merges the physical and virtual worlds together, and offers opportunities for different sectors, including those that make entertaining and engaging games (Javornik, 2016). Unlike virtual reality, AR is not cut off from reality, but, according to Craig (2013), it is a "medium in which digital information is superimposed on the physical world that is interactive in time and in both spatial and temporal registration with the physical world".

In the past five years, research interest in AR has increased, with researchers focusing on user adoption behaviour (Rauschnabel et al., 2017), marketing potential (Scholz & Smith, 2016), and user requirements (Scholz & Smith, 2016; Dieck et al., 2016). In general, these studies suggest that new and diverse factors drive consumer behaviour (e.g., wearability and perceived increase), so that user behaviour cannot be explained by single hypotheses, since different factors drive different patterns of usage.

Previous studies on Computer-Mediated Environments (CME) have shown that flow, quality of service, and satisfaction have direct or indirect effects on the intention to continue use. People play games to experience the sense of flow (Lee & Tsai, 2010), and this aspect has a strong effect on the willingness of a consumer to play a mobile game. As a consequence, this study examined flow-related variables first.

Probably, the most extensively studied Mobile Augmented Reality (MAR) game is Pokémon Go. Schade et al. (2020) evaluated the influence of playing Pokémon Go on the physical activity of students and found that the amount of distance travelled by university students did not increase. Madrigal-Pana et al. (2019) examined the perception of videogames and the use of Pokémon Go in Costa Rica and identified positive and negative perceptions of videogames mediated by age and level of education and that attitudes towards videogame playing depended on age and gender. Ma et al. (2018) analysed the relationship between the use of Pokémon Go and the physical activity of players and how the relationship varies between players with different levels of physical activity. Finco et al. (2017) studied how Pokémon Go allows people to walk in various urban places, encouraging users to be more involved and connect with other users, and discovered that it is one of the first mobile-based game plays that can promote a healthy lifestyle with a new way of communicating while transforming sedentary habits, with a wide potential for health education.

However, this game is mainly intended for young people and, as a matter of fact, most of the research carried out in AR in education has focused on how younger generations perceive and evaluate such applications, but there is a marked deficit in scientific research concerning the use of AR by adult learners.

As is well documented, adult learning differs from that of minors in five key respects, according to Courau (2000), which can be summarized briefly as follows: (i) adult learning is encouraged when instruction is specifically linked to the everyday life of an adult; (ii) if it is not followed by complete comprehension, adult learning becomes difficult; (iii) recognition of the aims of the educational project is significant for an adult learner; (iv) adult learners are directly interested in the instruction and the objects of learning, that is, they learn actively; and (v) adults learn more easily if they think they contribute towards a good cause or within the context of a community of learners. However, apart from the above, it should be noted that adults have a wide variety of learning types and thus, while minors engage in an educational process because they owe it to the state or their parents, adults learn and/or participate in an educational program for different reasons also (i.e., to use the knowledge and skills they will acquire either in their career or in their social advancement, to improve their financial situation, etc.). For instance, environment-focused learning theories (Robelia et al., 2011) place great emphasis on the environment, from which the stimuli that contribute to the learning process come, as well as human contacts and interactions between the person and the environment, eventually contributing to the transformation of learning into action. In addition, according to the theory of "personal creation" (Kelly, 1955), adult learning is not decided by external processes, but the learner is the creator of his own learning and information.

Although the mobile gaming industry is rapidly growing and competitive and since previous studies have already focused on Pokémon Go (Madrigal-Pana et al., 2019; Ma et al., 2018; Finco et al., 2017; Lee et al., 2018), other location-based AR mobile games deserve investigation as well. Previous research in applications of MAR games has identified both positive and negative factors affecting user experience (Chatzopoulos et al., 2017; Laine & Suk, 2019) and if the game is played by children, several positive experiences have been examined, such as enthusiasm, enjoyment, and arousal of curiosity (López-Faican & Jaen, 2020).

Pokémon Go, however, is not a game that would attract adult users' interest for very long and, certainly, is not the only Location-Based MAR game available; the game "Ingress" is probably the most relevant to adult users.

Moore (2015) observed that players of Ingress sought to assert and protect territories within physical environments by generating control fields, since players who use public landmarks as "portals" hack and protect these landmarks in order to gain control of specific areas. Ingress, like other types of urban mobile gaming, allows players to interact with both their mobile device and the urban environment at the same time.

Sdravopoulou et al. (2021) examined young, middle-aged, and elderly adults' opinions about the location-based MAR game Ingress by applying John Keller's ARCS learning motivation model (Attention, Relevance, Confidence, and Satisfaction). In that research, the efficacy of educating adults in this game was assessed quantitatively, on the basis of a quantitative approach (questions allowing only Likert-type answers).

This study focused on evaluating the location-based AR game Ingress to identify what players enjoy about the game, what they dislike, and what changes they would suggest being made to it. To explore these attitudes and experiences towards this game, it is necessary to use open questions, and thus the problem is how to analyze the participants' responses to the open questions. The standard method adopted in educational research in such cases is only "qualitative", consisting in discussing opinions and ideas expressed by the learners qualitatively, most commonly by using excerpts from the participants' responses (Cohen et al., 2008). This method, however, is not very informative when we have responses recorded from many participants. In such cases, we need a method for analyzing the content of their responses, which should also be (preferably) quantitative. It is at this point that this research suggests the use of two hitherto unexplored avenues for analyzing such qualitative data: "content analysis" in conjunction with the use of a statistical method based on the Jaccard index.

One of the key features of adult learning is that adults need to connect learning with previous experiences and also need to express their own opinions about what they learn. Considering this, and in view of the deficit in the literature related to how adults learn to play location-based MAR games, this research tackles the following questions:(i) What are the adults' main attitudes and opinions about Ingress? (ii) How do these opinions depend on user age? (iii) Can the Jaccard index be useful to quantitatively analyse the responses to open questions by more than one person?

2. Materials and Methods

The location-based MAR game Ingress was selected for this research project. It is a multi-player online augmented reality game (Sheng, 2013; Karpashevish et al., 2016; Hulsey & Reeves, 2014) that was developed and published in 2014 by Niantic, a Google spinoff company (the same company that created Pokémon Go), which announced that it had more than 7 million players in 2015. As a basis for overlaying game elements to real-world places, the game uses Google Maps.

There are two factions in Ingress ("Enlightened" vs. "Resistance") that players need to choose from which to identify with themselves. The main objective of the game is to take control of "portals" that are mapped to different locations in the real world, such as landmarks, public places, parks, or local businesses (Lee et al., 2017). By putting a mark (called a "resonator") at a portal, users mark the portal based on their team membership, and in this way, the portal is captured by the user (on behalf of her team) and the portal changes colour to either green for the faction of "Enlightened" or blue for the faction of the "Resistance". If players come across portals already run by the opposite team, by using in-game weapons such as "bursters" or "ultra-strikes", they can disable the influence of the opposing faction. By deploying "fields" connecting three portals into a triangle, players aim to take control of as many portals as possible and control a geographical area as large as possible. These game control activities can occur at different scales; "microfielding" is the term

for the activity of connecting portals that are highly concentrated in a small local region, while a large-scale activity that can span several states or even countries is called a “megafield”. Many participants and tight coordination are needed for the larger fielding efforts and are referred to as “field operations” (“field ops”). Eventually, the main objective of the game is to conquer as many portals as possible on behalf of a faction and to impose control over a large field.

To achieve the aim and objectives of the project, qualitative research methods (Cohen et al., 2008; Sofaer, 2002) were applied for data collection in order to assess the educational activity (person-to-person training in the game by the principal author of this research) that was carried out centered on Ingress. The survey questionnaire was composed of open questions and was developed specifically for this work. The questions were the following:

Q_1 How much does knowing the geography of the area facilitate your ability to play the game better?

Q_2 What is your opinion about the scenario of the game?

Q_3 How does playing locally in a global game makes you feel?

Q_4 How do you evaluate the idle phases during the game (intervals of repetitions or dullness)?

Q_5 What changes would you make to the game?

These questions allowed for the understanding of how the experience of playing Ingress fits into players’ lives. The open questions focused on experience and mood and on how players evaluate the game. These questions were phrased in a neutral manner to allow both positive and negative experiences to be shared. In the present case, interviews were appropriate as a qualitative method (Cohen et al., 2008), and the data obtained from the qualitative research were examined in detail by means of the method of “content analysis” (Krippendorff, 2004). The participants’ responses were analysed following methods of content analysis, which is “a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use” (Krippendorff, 2004). Content analysis as a method necessitates the use of advanced techniques and is independent of the researcher’s personal authority (Krippendorff, 2004).

The survey involved 24 users in Greece aged 20 to 60 years old. The participants (friends and relatives who were interested and willing to participate) were chosen on the basis of four characteristics: (a) they used an Android smartphone, (b) they understoodwritten and spoken English, (c) they could understand the game directions (either written or orally), and (d) they were not familiar with Ingress at all. Of the participants, 20.8% were graduates of secondary education, 8.4% were university students, 33.3% were university graduates, 33.3% held a master’s degree, and 4.2% held a doctoral degree.

The participants were trained to learn the basics of Ingress for two hours. Six steps are usually used in content analyses to describe the procedure:

(i) Unitizing: the process of systematically separating text segments that are relevant to the main focus of the study.

(ii) Sampling: by restricting observations to a manageable subset of units that is statistically or conceptually representative of the set of all possible units, sampling helps the analyst to save time or other resources.

(iii) Coding: the process of converting information into code; the process of defining or classifying recording units according to the categories of the chosen analytical constructs. In this phase, main themes and subthemes are identified within the responses.

(iv) Data reduction: This step meets the needs of analysts, who need efficient representations of large amounts of data.

(v) Inferring conclusions: In content analysis, this stage employs an understanding of how the variable accounts of coded data relate to the phenomena the researcher is interested in learning about.

(vi) Narrating: the researchers make their findings understandable to others by narrating the responses to content analysts' questions.

The 24 participants of this research were evenly distributed among age groups: three age groups were defined with 8 persons in each group and at 15-year intervals: 20–35, 36–51, and 52–67. The means and standard deviations per age group are given in table 1.

Table 1

Age groups with the number of participants per group, mean age, and standard deviation.

Ages	Participants	Mean Age	Standard Deviation
20–35	8	28.6	5.55
36–51	8	45.9	4.94
52+	8	56.6	1.92

Content analysis was performed on the users' responses both qualitatively (to identify characteristic sentences expressing attitudes and opinions) and quantitatively. For the quantitative assessment of similarities between responses for each question and subtheme, the Jaccard similarity index $J_{ij}$was calculated pairwise for every pair i, j of participants (Stefanovič et al., 2019):

$$J_{ij} = \frac{M_{11}}{M_{01} + M_{10} + M_{11}}$$

where M_{11} denotes the number of agreements between respondents on a subtheme ("yes-yes"), M_{01} is the number of disagreements where the respondent *i* responded "no" and the respondent *j* responded "yes", and M_{10} is the number of times with the reverse responses. Although originating from ecology (Jaccard, 1901), the index has found applications in many domains (Hamers, 1989;Leydesdorff, 2008; Egghe, 2009;Leydesdorff et al., 2017; Fried. 2017; Verma & Aggarwal, 2020).

After the creation of the 24 × 24 matrix of Jaccard indices for all 24 participants of this research showing agreement or disagreement among participants for each subtheme, the mean Jaccard index by pairs of participants *i*, *j* for all *n* raters can be calculated using the following formula:

$$\hat{J}_{ij} = \frac{2}{n(n-1)}\left[\sum_{i=1}^{n}\sum_{j=1}^{n} J_{ij}\right]$$

Consequently, the inter-age group Jaccard index $J_{u,v}$ for age groups *u,v* (with *u*=1,2, and3 and *v*=1,2,and 3) is calculated, and hence, the sum of the values of the similarity indices for all subthemes of each question and for all participants, by age group, is represented by:

$$J_{u,v} = \sum_{u,v}\left(J_{ij}\right)_{u,v}$$

For all age groups (three in this case), the mean Jaccard similarity index for each question and age group, taking into account all subthemes and among all participants by age group is:

$$\hat{J}_{u,v} = \frac{\sum_{u,v} \left(J_{ij}\right)_{u,v}}{\hat{J}_{ij}}$$

A Chi-square test was performed to test the significance of the entries of the resulting matrices for each and all questions.

3. Results

The results concern the fields examined: the role of geography in playing the game better, the scenario of the game, the feeling of playing locally in a global game, the role of the idle phases, and the suggestions for improvement of the game.

3.1. Knowledge of Geography Facilitates the Game

When asked if the knowledge of the geography of the participants' area helped them to play the game better, the vast majority of participants answered in the affirmative for reasons such as that in an unknown area they would face additional difficulty and that they saved time, enjoyed it more, and felt safe.

The thematic "knowing the geography facilitates you to play the game better" was found to be related to 13 subthemes, as follows: it is decidedly a game based on geography, it gives motivation to continue playing, unknown areas are associated with more difficulty, knowledge of the area helps to gain time, the game has suspense, there are texts with information about the local area, the game can be enjoyable, it gives a sense of safety, requires concentration, can be indifferent, is based on walking, experiential knowledge of geography helps the user play it better, and it motivates the user to know other areas (figure 1). Percentages correspond to the number of mentions in the participants' responses related to the main thematic "knowing geography facilitates the game".

As many as twelve subthemes were evaluated positively and one negatively, and 50% of the adult learners agreed that Ingress is a game based on geography and that by knowing the area they save time. The mean similarity of responses between the participants was calculated with the Jaccard similarity index, which was 0.11 for this question. Quoting two characteristic responses:

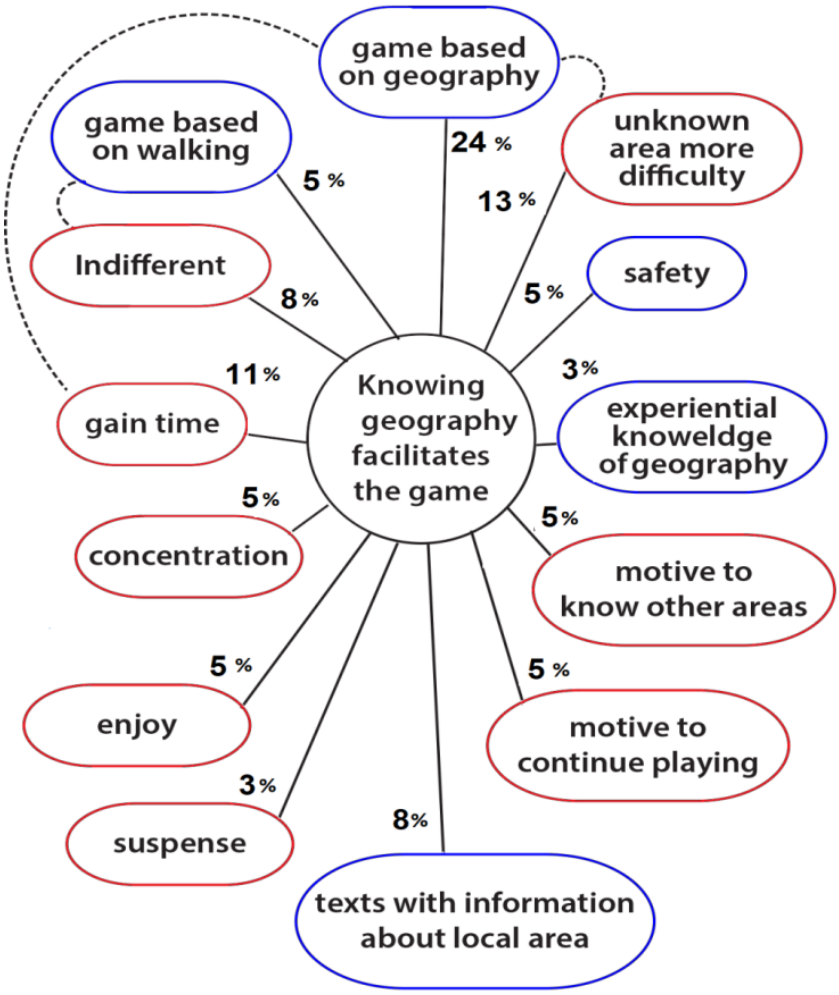
"It is not possible to play Ingress if you do not know the geography of the area that plays it very well. It is a geographical game combined with augmented reality. This is because either you will play (so it presupposes knowing where you are going without wasting time), or you will be looking to find the portals (so you are not playing but you are looking for and learning the area)".

"The fact that I am unfamiliar with the area discourages me so much that I want to play it less than once or twice a month. I do not like searching areas, either with Ingress or without it. If I were in the city where I was born and raised, I would play it every day. That is, for a game like Ingress, knowing the area you are playing in is a determining factor that can function either very positively or very negatively".

Analyzing the subthemes, it was revealed that the subtheme "game based on geography" was highlighted more by the 36–51 age group (with a percentage of 67%), followed by the 20–35 age group (with a percentage of 22%) and the >52age group (with a percentage of 9%). Interestingly, those who expressed the opinion that knowledge of the area's geography did not help them play the game any better mentioned as a reason that Ingress is based on movement, and therefore, it is unavoidable to move into unknown areas.

Figure 1

Subthemes resulting from the content analysis of the responses to question 1. Percentages correspond to the number of mentions related to the main thematic "knowing geography facilitates the game".



Note: Some subthemes were mentioned more than once by the participants who also mentioned the subthemes that are connected with dotted lines. Subthemes in red relate to the user, while those in blue relate to the game.

3.2. Scenario of the Game

Opinions varied regarding the Ingress scenario. The content analysis showed that the central thematic ("scenario of the game") was related to 12 subthemes (see figure 2., in which the percentages correspond to the number of mentions related to the main thematic "knowing geography facilitates the game").The content analysis also indicated that it is fascinating to be part of a group, the scenario gives suspense to the user while they may also appear indifferent, relates to an interesting discussion about the evolution of humanity, allows the identification with one of the groups and for communication among team members, is addressed to all ages, the game's oral instructions give more information about it, it is challenging, reminiscent of fairy tales or conspiracy theories, and that it is interesting as it refers to CERN.

As many as 41% of the answers indicated that the scenario of the game interestingly reflects part of the discussion about the evolution of humanity, while

equal percentages (10.3%) followed the opinions that the game allows communication between the team members as well as the opinion that it is indifferent.

Among the opinions expressed, the following two were perhaps most characteristic:

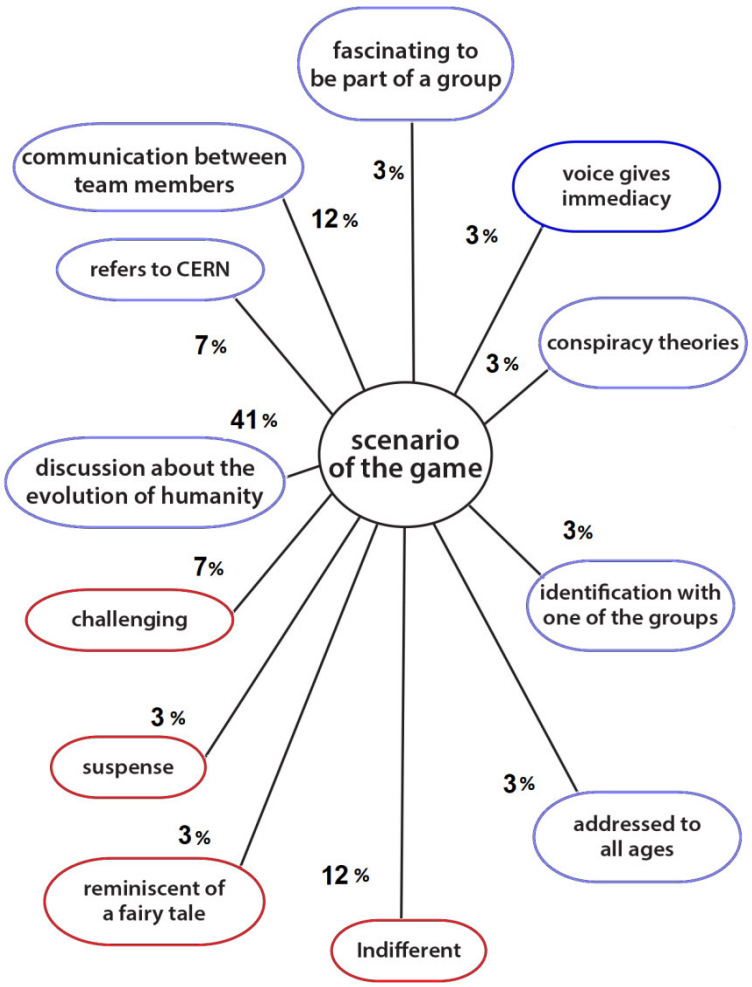
"It's perfect. First of all, it has an interesting scenario, while I expected it to be monotonous. You are member of a team and you are called to defend your team's interests, you make friends and allies; you are not alone. Each area is marked either by your own team or by the opponents and you need help to advance the game. You do not know what will happen next and you also have a purpose for which you are fighting for; a mission".

"I liked the script. It also has to do with conversations. I hear so much about technology; to what extent have new technologies changed our lives and since the human species is evolving, such or a similar evolution is inevitable. And on this issue there are various views, theories".

In fact, the subtheme "discussion about the evolution of humanity" concentrated as many as 58% of the mentions of the 36–51age group, followed by the 20–35 age group, with 25%, and finally the >52 age group, with 17%. The mean similarity of the responses between the participants was calculated with the Jaccard similarity index, which was 0.212.

Figure 2

Subthemes with percentages of mentions related to the main thematic "scenario of the game" (question 2).



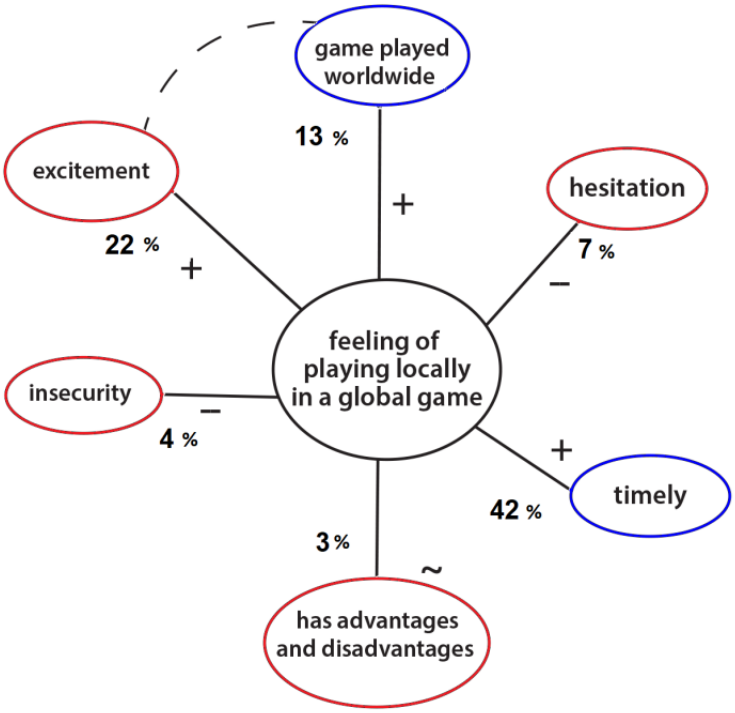
Note: Subthemes in red relate to the user, those inblue relate to society, and those in dark blue relate to the game.

3.3. Feeling of Playing Locally in a Global Game

When asked about how participants feel about playing locally in a world game, feelings of excitement, insecurity, and caution were reported. It was also pointed out that the game was relevant to most of them, and indeed, for some participants, it was the only game they knew in which it is possible to play from one's own country on a global scale. Specifically, the content analysis of the responses to question 3 showed that the thematic "the feeling of playing locally in a global game" was related to six subthemes (figure 3): excitement, current, game played worldwide, hesitation, insecurity, and has advantages and disadvantages. Two indicative responses were:
"This side of the game is also relevant. We now live in a globalized society, whether we realize it or not. Some of us (realize it) to a higher degree. As for me, it is a daily experience to meet people from different countries, because I am doing my master's degree in England and in my department my fellow students are from 11 different countries". "It is good to be accustomed to thinking locally but also through a global context. Because we are used to thinking only locally and without being part of a broader plan and of course without a specific ideology. On the other hand, for me personally, I felt it was very binding that in order to be able to play the game, I had to choose one of the two warring factions". Of the six subthemes, three were evaluated positively, two negatively, and one neutrally. The mean similarity of the responses between the participants was calculated with the Jaccard similarity index, which was 0.279. The subtheme "timely" concentrated 42% of the mentions. Next was "excitement", with 22% of mentions; therefore, these two subthemes accounted for over 50% of mentions. The subtheme "timely" was focused more in the 20–35 age group, with a percentage of 46%, then the >52 age group, with a percentage of 31%, and finally the 36–51 age group, with a percentage of 23%.

Figure 3

Subthemes with percentages of mentions related to the main thematic "feeling of playing locally in a global game" (question 3).



Note: Two subthemes were mentioned more than once (with dotted lines). Subthemes in red relate to the user, and those in blue to the game. The signs +, −, and ~ represent the learners' disposition towards the subtheme to which these signs relate (positive, negative, and neutral disposition, respectively).

3.4. Idle Phases

Initial descriptive statistics showed that 83.33% of the players rated Ingress as extremely interesting, without boring phases between activities, as one activity follows another with specific goals that the player is required to accomplish. Special mention was made of the fields that the map shows as well as the fact that the portals are in real places in the area, such as shops and cultural heritage sites. As for the participants who stated that it has boring intervals, the causes pointed out included the need to walk in order to play the game, long distances between portals, exposure to weather conditions, and the slow transition from one level to another.

In particular, the responses to question 4 can be summarized as follows. The thematic "idle phases" were related to eight subthemes (figure 4): they may be due to large distances between portals, they are seldom experienced because the game has clear goals at every level, the map of the area provided by the software is helpful, activities run smoothly, it is easy to exit and reenter the game at any time the user wishes, running between levels is relative slow, the software's oral instructions are helpful, and the weather conditions affect the play.

Of these eight subthemes, five were evaluated positively, two negatively, and one both positively and negatively (the weather conditions), and in 1/3 of the cases, the same players mentioned at least two subthemes. All the positive subthemes (clear goals at every level, real map of the area, smoothly running of activities, easy exit and reenter and weather) were mentioned more than once.

The subtheme "real map of the area" was mentioned in 31% of the mentions. This was followed by the smooth running of activities, with 24% of mentions; therefore, these two subthemes accounted for over 50% of mentions.

The subtheme "real map" was equally emphasized by the 20–35 and >52 age groups, with a percentage of 36%, and less by the 36–51 age group, with a percentage of 28%.

From the qualitative analysis of the content, two players characteristically responded:

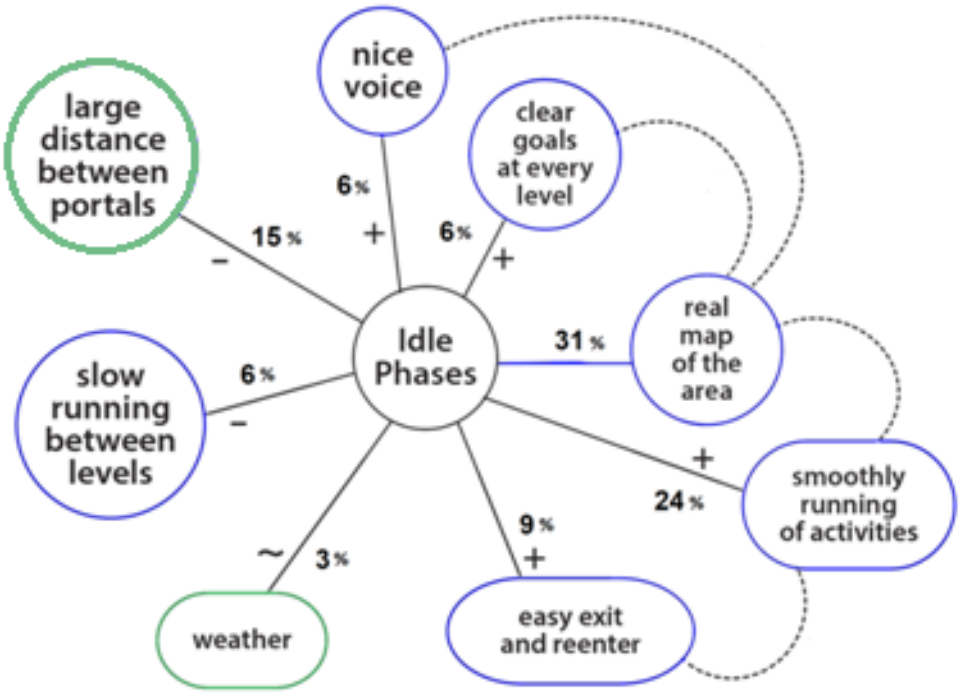
"If it was even a little boring, I would tell you right away and I would not bother a second time. But I liked it that such a real and challenging game has been created, so I tend to deal with it" and

"It is boring to walk from one place to another, especially when they are somewhat distanced. Just that. Because otherwise it is a very convincing game".

The mean similarity of the responses between the participants was calculated with the Jaccard similarity index, which was 0.17.

Figure 4

Subthemes (with percentages of mentions) related to the main thematic "idle phases", as derived from the content analysis of the responses to question 4.



Note: The subthemes "clear goals at every level", "real map of the area", "smoothly running of activities", "easy exit and reenter", and "weather" were mentioned more than once by the participants, who also mentioned the subthemes that are connected with dotted links. Subthemes in blue relate to the game, and those in green relate to the environment. The signs +, −, and ~ represent the learners' disposition towards the subtheme to which these signs relate (positive, negative, and neutral disposition, respectively).

3.5. Suggested Changes to the Game

When asked about the changes proposed to the game by the participants, some of the opinions expressed were that they would add shapes, turn the sound louder, make colours more lively, and insert more informative texts. However, most participants answered that they would not make any substantial changes to the game.

The thematic "changes to the game" was related to nine subthemes, as follows (figure 5): more shapes, more intense colors, more texts, louder sounds, not personalized shapes, logo for each group, more portals, fewer symbols, and, expectedly, some responded that no changes would be necessary (32%).

Some characteristic answers were:

"No changes to it. First of all, it's a game and so it's expected to have shapes, and colors and music. And because it is an augmented reality game, the relationship with the natural environment is very welcome. An augmented reality game can not be deprived from shapes and sounds, because it would not be a game after all, and on the other hand, it cannot be full of such, because it would not be "augmented" reality but "virtual" reality instead".

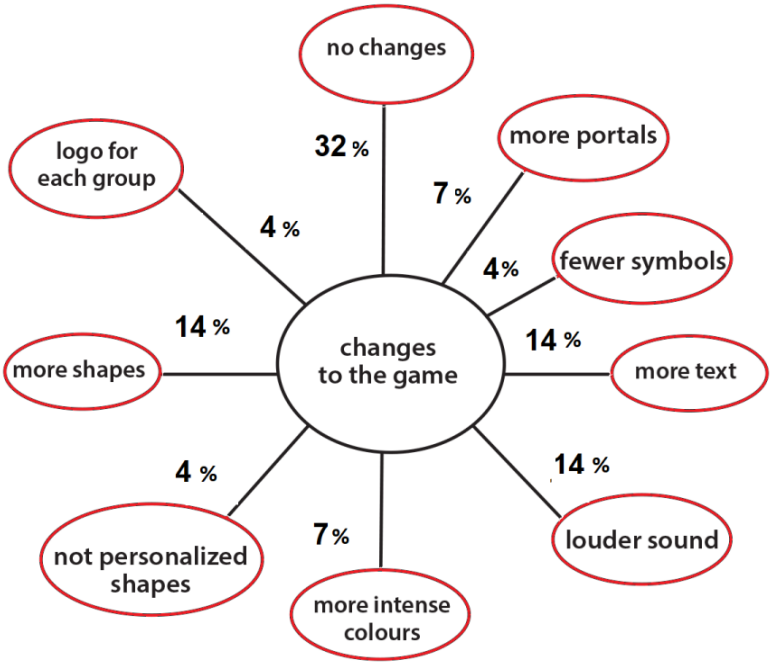
"Yes, much more informative texts about streets, squares, parks, that is, this street is called ... and a few words about the name of the street, below this square is called a square... a few words about the name of the square and then it should be full of

various information. As for the colors, I would make them a little more intense, they look very neutral to me".

The subtheme "no changes" was equally mentioned by the 20–35 and 36–51 age groups (with percentages of 44%), followed by the >52 age group(with a percentage of 12%). The mean similarity of the responses between the participants was calculated with the Jaccard index at 0.17.

Figure 5

Subthemes with percentages of mentions related to the main thematic "changes to the game" (question 5).



Note: Subthemes in red relate to the user.

From the values of inter-age group indices of similarity $J_{u,v}$, and as concerns question 1 about whether the knowledge of the geography of their area helped the users in the game, the 36–51 age group completely agreed with the >52 age group that it is a game fundamentally based on geography, as well as that playing it in an unknown area is a source of extra difficulty.

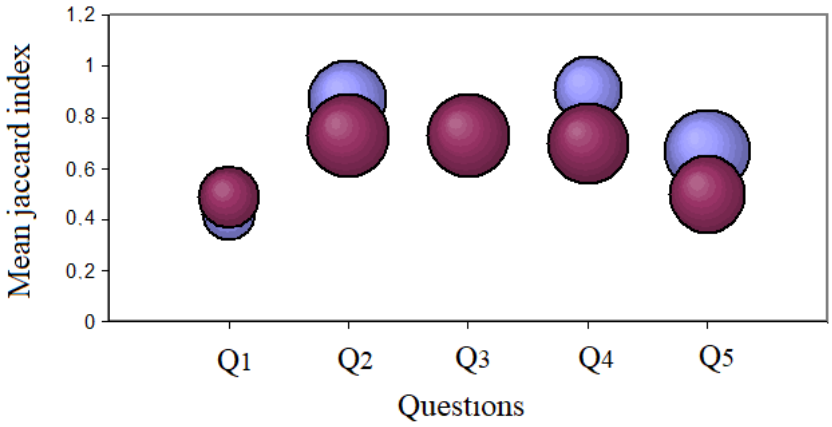
With respect to question 2 about the game scenario, the 36–51 age group agreed more with the >52 group, mainly in the view that it interestingly reflects some of the current debate on the evolution of humanity.

As regards question 3, which deals with how the adult learners felt when they played locally in a worldwide game, a higher agreement was observed between the 20–35 and >52 age groups, primarily in that Ingress is a timely game, and then with balanced feelings of both excitement and insecurity. In question 4 on whether there are idle phases in the game, the 20–35 and >52 age groups agreed more that the game does not present idle phases for reasons such as that it has a built-in real map, a smooth flow of activities, and it is easy to exit and reenter.

Finally, as relates to question 5 (on whether the users suggested any changes to the game), the highest agreement was observed between the 20–35 and >52 age groups that they would not make any change to the game. Hence, for most questions, higher agreements were observed between the 20–35 and >52 age groups (figure 6). This was somewhat unexpected; for most questions, the lowest agreement was between the 20–35 and 36–51 age groups, meaning that the game was perceived differently by people aged 35 or more.

Figure 6

Values of the mean Jaccard index (with their standard deviations) per question, for the comparisons between the 20–35 and 36–51 age groups (purple balls) and 20–35 and >52 age groups (blue balls).



Note: the 20–35 and >52 age groups had higher means of agreement than the 20–35 and 36–51 age groups for all questions except for question 1.

The matrices of the Jaccard similarities in responses for all subthemes for all the age groups per question are given in table 2, and the levels of confidence following the test for statistical significance are given in table 3.

Table 2

Sums of Jaccard similarity indices $J_{u,v}$(for ages u and v) per question Q_k for all responses, all subthemes, and all three age groups, per question.

	Question 1			Question 2			Question 3			Question 4			Question 5		
	Age groups			Age groups			Age groups			Age groups			Age groups		
Age groups	20-35	36-51	52+	20-35	36-51	52+	20-35	36-51	52+	20-35	36-51	52+	20-35	36-51	52+
20-35	5.7	8.5	6.7	17.3	15.3	13.0	6.0	15.3	15.8	6.5	20.8	5.5	2.8	13.4	11.1
36-51		2.0	5.0		4.0	8.0		11.0	21.0		6.8	5.7		5.3	10.5
52+			1.8			1.0			5.7			2.0			4.5

Table 3

Level of significance of the values of $J_{u,v}$for each question.

Question	Interval Level of Significance α
Q_1	90% <α< 95%
Q_2	99% <α< 99.5%
Q_3	97.5% <α< 99%
Q_4	95% <α< 97.5%
Q_5	α> 99.9%

4. Discussion

Our study revealed that adult learners in three different stages of adulthood focus on different issues, which are ideally revealed through content analysis ("subthemes"). The theory and practice of adult education have revealed that their responses are, in most cases, more complicated in meanings and attitudes than those of young people. This is reflected by the fact that their personal experiences and professional expertise often intermingle with the way they judge anything new they learn (Garrison, 1991). For this reason, content analysis may be more appropriate to discover what they think about the subject they learn.

Open ended questions, in contrast to questions that are in closed form, are usually studied by content analysis, which is a research technique for the objective, systematic, and quantitative description of the manifest content of the communication (Berelson, 1952). Another issue with open-ended questions is the role of missing data (either non-valid responses or skipped questions) in inferring results from them since the amount of missing data is usually higher for open-ended questions. This problem is specific to self-administered questionnaires because there is no other interviewer to check for improper responses and/or any omitted items (Reja et al., 2003). In addition, since some respondents answer in broad terms, the researcher may have to focus on particular answers, especially when it comes to attitudinal questions, because there is no interviewer to probe and inspire respondents to provide more detailed responses (Reja et al., 2003).

Content analysis is more complex and complicated than quantitative analysis (Polit & Beck, 2004), and it has no clear rules for data analysis, as each investigation is unique and the outcomes are determined by the investigator's talents, insights, observational abilities, and style (Hoskins & Mariano, 2004). One of the challenges of content analysis is that it is very flexible, and there is no one-size-fits-all approach. Researchers must determine which combinations are most suitable for their specific problems (Weber, 1990), which makes the research process both difficult and fascinating. This research process has received little attention in the literature of Information and Communication Technologies (ICTs) in education. Backman and Kyngäs (1998) described the beginning of the categorization process as chaotic since researchers have many apparently unconnected pieces of knowledge to cope with and classify. Another issue is that the content of the narrative is seldom linear, and transcribed interview paragraphs can include elements from multiple categories (Hoskins & Mariano, 2004; Dey, 2003). Reporting and presenting the study's findings can be difficult as well since the findings are the product of a multi-phase process. Some aspects of this process can be described in great detail, but others, such as the researcher's own behavior and insights, may be difficult to express (Backman and Kyngäs, 1998).

However, our study nevertheless has some limitations. One is the small number of game players, and another is that it is possible that some of the findings of this study might be biased by particular geographical settings (i.e., different cities and cityscapes within the same city) or by the participants' particular demographics, and thus further research under different conditions and participants might be needed. In addition, with alternative classifications of the three age categories, different results might be derived. This particular classification into three categories did, however, reveal some similarities and differences between age groups. Some responses to multi-parametric questions, however, may present rather unexpected results. This was the case with the fifth question in this study, to which as many as 32% of the participants responded that they would not make any changes to the game.

However, content analysis, as a research methodology, is shown to offer new perspectives, improving a researcher's comprehension or advising realistic behaviour,

and it is thus an appropriate method for analyzing data, particularly those derived from research in adult education (Hamers, 1989).

In this paper, content analysis was ideally combined with the Jaccard similarity index because it was applied to record agreements and disagreements between subthemes, and in this way, it allowed us to analyze qualitative data (i.e., the subthemes) quantitatively. Furthermore, the combination of content analysis and the Jaccard similarity index can be used in similar studies also (i.e., for analyzing texts relating to user interface and qualitative software evaluation). Until now, quantitative content analysis was used either by measuring the frequencies of words in a text or qualitatively only (exploring meanings and semantics).

As regards the game itself, the subtheme "knowledge of geography facilitates playing the game better" seemed to occupy a central position among the opinions expressed in answering question 1. Ingress, like other types of urban mobile gaming, allows players to interact with both their mobile device and the urban environment at the same time. Pervasive games have historically been used to investigate such activities as an extension of the gaming world into everyday spaces (Montola et al., 2009; Nieuwdorp, 2007). By contrast, urban play has been debated as a natural part of daily life, with parallels drawn between historically situated urban mobility activities (Hjorth, 2011). In the case of urban mobile games such as Ingress, play is influenced by socio-cultural circumstances prevailing in an area, while at the same time, the play generates a new, unique perception of urban environments (Verma & Aggarwal, 2020) that is based on one of AR's most characteristic feelings, the "immersion". According to Gong et al. (Gong et al., 2017), location-based mobile games are gradually turning "serious" ordinary spaces into playful spaces, thereby blurring the lines between play and everyday life. The use of mobile devices and the physical movement of players in space has increased the importance of the social construction of space. In addition, the game reveals new information about people's mobility habits (Davis, 2017; Söbke et al., 2017; Nur &Tozal, 2018).

From the responses to the question concerning the scenario of Ingress, it was noted that the subtheme highlighting the fact that the game convincingly relates to the evolution of humanity accounted for 41% of the respondents, and this points to a much-discussed and timely issue regarding socialization through MAR (Mobile Augmented Reality) games. It is widely recognized (Chang & Tan, 2010; Reitmayr &Schmalstieg, 2003; Burden & Kearney, 2016) that location-based AR is more suitable for building scenarios and promoting collaboration. Moreover, naturalistic approaches applied to location-based MAR are suitable for designing multidisciplinary applications, can be used for training, and have the potential to be designed so as to account for locality and context (Sdravopoulou et al., 2021).

When participants were asked how they felt while playing locally in a global game, 22% of them expressed enthusiasm that the game is adapted to our daily lives, which mostly follows the ubiquitous "glocalization" patterns of contemporary life. However, because of the real-world nature of Ingress, Windleharth (2020) stated that the "Ingress Communities of Practice" (CoPs) face unique challenges, such as risks to physical safety in order to achieve the game goals, "spying" (with attempts to gather information from in-game and out-of-game systems)while monitoring real-world locations and behaviors and risking real-world identity exposure, along with a range of other issues (such concerns were also mentioned by some 11% of the respondents in our study). The Ingress CoPs have developed specific practices to solve problems that blur the line between digital and real-world gaming, encouraging players to self-police and change their actions to suit group norms (Windleharth, 2020). The vast majority of responses were that the game is very interesting, that its activities flow smoothly, and that there are clear goals at every level. Those players who stated that Ingress has idle phases mentioned the need to walk long distances between portals,

the fact that the levels proceed slowly, and the weather factor (which may impose restrictions to play).

Previous studies (Malik et al., 2016; Malik et al., 2019; Taddicken, 2014) have shown that younger adults (18–35 years) are more familiar with videogames than older adults (67 years and older). However, Madrigal-Pana et al. (2019)agreed that game exposure and practice, rather than age, could be to blame for any negative attitudes towards games. Indeed, new research shows that once older adults grasp and play videogames, their negative attitudes gradually fade away (Ferguson & Donnellan, 2017; Ivory &Kalyanaraman, 2009). This coincides with the findings of our research with Ingress, in which a positive attitude to Ingress was revealed, even by adult users of the >52> age group. This backs up the idea that, at least in part, questions about such games stem from a lack of experience with the medium. This is also supported by research by Przybylski (2014), which found a connection between negative attitudes towards video games and generational issues.

5. Conclusions

This study reveals that, so long as the scenario of an MAR may appeal to adult users, the game can very well be approached and played by adults of various ages and educational backgrounds. Location-based MAR games offer the additional advantage to adult users that they combine physical activity with the excitement offered by AR technology. Particularly as concerns the game Ingress, we can conclude that regarding the playing of Ingress by adult users who play it for the first time, those over 36 years old focused on the fact that it is primarily a geographical game and its scenario reflects interesting discussions about the evolution of humanity. Next, whether the game is boring and how they feel playing locally in a worldwide game and with respect to any changes they would suggest, the highest agreement among participants' views was observed between the 20–35 and >52age groups, who commented that the game does not have idle phases, that it combines excitement with insecurity, about playing in their country within a game of planetary proportions, and that they would not suggest any notable change in the game's design or settings.

In addition, methodologically, it was shown that content analysis presents the researcher with several advantages: texts derived from interviews and/or answers to open questions of educational research can be analyzed both qualitatively and quantitatively with Jaccard indices. The method proposed here shows how, after the themes were identified from within the typical content analysis methods, the subthemes may subsequently be analyzed by means of Jaccard indices in order to derive assessments of agreement of the participants' responses.

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4.4. Paper P4

Network Analysis for Learners' Concept Maps While Using Mobile Augmented Reality Gaming

Konstantina Sdravopoulou, Juan Manuel Muñoz González and María Dolores Hidalgo-Ariza

Abstract: Using mobile augmented reality games in education combines situated and active learning with pleasure. The aim of this research is to analyze the responses expressed by young, middle-aged, and elderly adults about the location-based mobile augmented reality (MAR) games using methods of content analysis, concept maps, and social network analysis (SNA). The responses to questions related to MAR game Ingress were collected from 36 adult players, aged 20–60, from Greece, and subsequently analyzed by means of content analysis, concept maps, and social network analysis. Our findings show that for question 1 (How do you feel when you endow the geographical space with personal preferences?), there was a differentiation of the answers between age groups with age groups agreeing in pairs, the first two and the last two, while for question 2 (Do you think that the game offers opportunities for learning and teaching geography, building on your previous geographical knowledge?), there was an overlap in responses of participants among age groups. It was also revealed that the MAR games foster a constructivism approach of learning, as their use learning becomes an active, socially supported process of knowledge construction.

Keywords: mobile augmented reality; MAR games; network analysis; networks and education; networks and content analysis; ingress

1. Introduction

Games using mobile technologies are complex mechanisms that create multifaceted relationships among players. The potential of LBMGs (location-based mobile games) can be explored in informal education settings (Lee & Hsu, 2021; Lin et al., 2021) while addressing wide and diverse fields of research such as mobile learning (m-learning), situated learning, and game-based learning (Spallazzo & Mariani, 2018). According to Schito et al. (2015), LBMGs provide teachers with methods of conceptualizing classes with long-term learning impact, through ludic, flexible, and innovative approaches. According to a list of Naismith et al. (2004), mobile learning tends to be an informal process that occurs over time on the basis of mobility, which is a key property characterizing people's interactions with technology (Kukulska-Hulme et al., 2009), combining experience of retrieving data through various media. As a consequence, a broad concept of mobility emerges: one that tends to be multifaceted in five interconnected dimensions: mobility in physical space (which refers to people on the move), mobility of technology (which refers to the portability of devices as well as the ability to transfer attention between them), mobility in conceptual space (which refers to mobility from one concept or subject to another), and mobility in social space (which refers to the various contexts in which learners operate and learning is dispersed over time, and it describes learning as a combined experience that happens through different media and across time). As these five main features of mobility are available to LBMGs, players walk around the city

with a portable device, searching for clues and content, and they can socialize with other players and non-players. As a result, mobile learning tends to be an informal method of acquiring information and experience while on the move, which is supported by personal and public technology (Kukulska-Hulme et al., 2009).

The "situated learning model", mainly developed by Lave and Wenger (1991), is based on the relationship with the environment, whether experienced by learners/players through contextual knowledge given by the mobile device or directly exploring the real world. Following this model, learning is a dynamic process characterized by social engagement (Naismith et al., 2004) that necessitates involvement and cooperation, rather than merely a personal acquisition of information. Furthermore, presenting information, and thus understanding, in a real-world sense, gains a lot of impetus.

In his essay "Augmented Learning", Klopfer (2008) argued about the potential of mobile-supported learning in real-world settings, discussing how mobile technology can enhance and augment the learning experience. He theorized that LBMGs are effective means of informal education as well as enforcement of formal education by combining the ability of mobile games to promote interaction and learning outside of formal education activities with the possibility of embedding learning in authentic environments through location-based technologies (Huizenga et al., 2007). This reasoning is supported by Prensky (2001), who claims that the combination of enjoyable and immersive entertainment with serious learning is at the heart of digital game-based learning—a combination that the author sees as a way of reaching out to contemporary learners in both formal and informal environments.

Previous research (Huizenga et al., 2007; Liu & Chu, 2010) found that games could help students learn the English language more effectively and be more motivated in context-aware learning environments. Avouris and Yiannoutsou (2012) noted the need for more research into how the architecture of LBMGs affects user experience. The key challenge for designers of LBMGs, according to Alnuaim et al. (2016) is to successfully integrate them into authentic educational activities that are important to a student's work in order to enhance the learning experience. Hung et al. (2012) found that spatial learning tools improve students' spatial perception as well as their academic performance. Slussareff and Boháčková (2016) compared the efficacy of knowledge acquisition and interaction from learning by designing and learning by playing LBMGs, and they found a positive impact on knowledge acquisition. Hwang et al. (2016) found that an augmented reality mobile gaming approach involving a learning device that detects students' locations boosts students' learning attitudes and achievements.

Yet, despite the expansion of these technologies in education, there is a remarkable deficit in our knowledge about what adult learners think and feel about LBMGs. In adult education, quite often, it is more preferable to use qualitative research (with open questions or interviews), because it allows the researcher to delve deeper into this kind of learners' verbal expressions, which can be more revealing of their attitudes and dispositions about the subject they learn. Furthermore, we still lack knowledge about the way adult learners of LBMGs either build on previous experiences or knowledge they may have or create new ones: we do not know how constructivism works in adult education in which MAR games are used (Bressler et al., 2018; Barma et al., 2015; Koutromanos & Styliaras, 2015).

One approach to the methodological problems of treating qualitative data of educational research is to use "concept maps" (CM). A concept map can be used to frame a research project, reduce qualitative data, evaluate themes and interconnections in a thesis, and present findings (Novak, 1984). "A concept map is a schematic device for representing a set of concept meanings embedded in a framework of propositions" (Novak et al., 1984). The larger, more inclusive concepts are placed at the top of the concepts hierarchy, with linking to sub-concepts. Concept

maps are particularly useful to map out concepts from interviews and open questions. From them emerge the main concepts and sub-concepts which are mentioned repeatedly by the learners, and hence, two needs arise: the need to visualize the relationships among concepts and the need to explore quantitatively their occurrence in the participants' responses. One possibility to address both these needs is to use networks, but this avenue has never been explored before. SNA was used by McLinden (2013) to analyze concepts mentioned by individuals; the data were represented by social networks and analyzed by means of betweenness centrality. While SNA has a long history in humanities and it is also used to evaluate programs (Cross et al., 2009; Penuel et al., 2006), they have never been used for content analysis before, either for educational research or not.

Thus, from the examination of the literature available so far, the following observations can be made:

(i) Despite the plethora of studies that apply concept maps in education, how adult users assess MAR games (LBMGs in particular) with concept maps has hitherto never been examined or explored. Nor has learning how to play location-based MAR games been examined by using methods of network analysis.

(ii) Constructivism in education in MAR games has poorly investigated so far.

(iii) Networks have never been used to explore the interplay among concepts and sub-concepts as they result from content analysis (not only in education but in general).

(iv) The role of constructivism in education using MAR/LBMGs has been poorly examined.

Hence, by focusing on the MAR game Ingress, the present research addressed these research gaps by concentrating on the following research issues as concerns this particular game:

(i) What are the most important views and attitudes that adult learners have toward Ingress?

(ii) How do these views differ depending on the user's age?

(iii) What are the advantages of using networks as models for the analysis of adult learners' concept maps in education?

2. Materials and Methods

Qualitative research methods were applied for data collection in order to assess the educational activity that was carried out centered around the location-based MAR game Ingress, which is selected due to the fact that it is a game suitable for adults and, moreover, it is a widely used open access location-based MAR game, which can be played without ethical concerns by users of all. Two open questions were posed to the participants, which aimed to examine the impact of constructivism through game-based learning:

Q_1: How do you feel when you endow the geographical space with personal preferences?

Q_2: Do you think that the game offers opportunities for learning and teaching geography, building on your previous geographical knowledge?

These questions explore the impact of a constructivist approach (Vygotsky, 1980; Bruner, 1996) to this adult education research, in which learners learn actively and construct new geography-bound knowledge and experiences by using the location-based MAR game Ingress and how these new knowledge and experiences are based on their prior knowledge.

The data obtained from this qualitative research were examined in detail by means of methods of "content analysis", "concept maps", and "social network analysis" (figure 1).

The research involved 36 adult learners in Greece, aged 20 to 60 years old. Participants were trained for 4 h, and the following day, they played Ingress for 3 h. They visited all points of interest (Ingress portals) that were close to their neighborhood during those hours. Various usability issues affected their experience, and all voices (interviews) were recorded and analyzed with the method of content analysis. They were chosen on the basis of four characteristics: (a) they had already been using an Android smartphone, (b) they understood written and spoken English, so they could understand the directions that the game provided them (either written or orally), and (c) they were not familiar with Ingress at all. Of the participants, 19.44% were graduates of secondary education, 8.33% were university students, 44.44% were university graduates, 22.22% held a master's degree, and 5.55% held a doctoral degree.

The 36 participants of this research were evenly distributed per age group: four age groups were defined with 9 persons in each group and at 10-year intervals: 20–30, 30–40, 40–50, and 50–60. The means and the standard deviations per age group are given in table 1.

Table 1

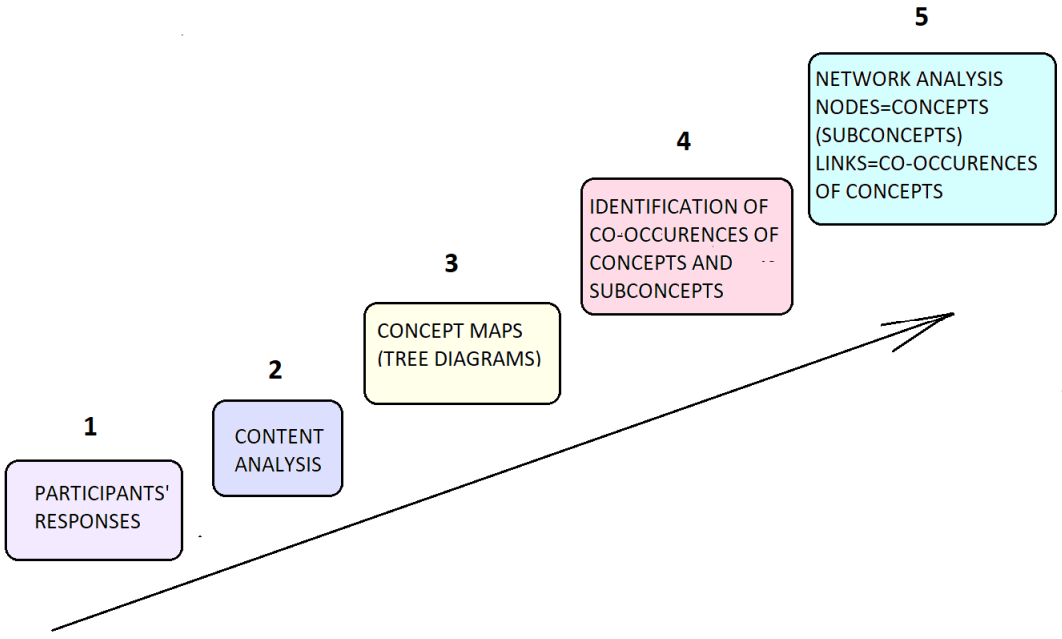
Age groups with number of participants per group, mean age, and standard deviation.

Ages	Participants	Mean Age	Standard Deviation
20–30	9	24.4	3.216
30–40	9	33.0	2.260
40–50	9	43.3	1.885
50–60	9	54.0	2.867

The research project was articulated in five phases, as shown in Figure 1.

Figure 1

The five phases of the research project.



1. The first step was the recording of the participants' responses, after they were trained in the use of Ingress and began using it.

2. Their responses were analyzed following methods of content analysis, which is "a research technique for making replicable and valid inferences from texts (or other meaningful matter) to the contexts of their use" (Krippendorff, 2004). Content analysis as a method necessitates the use of advanced techniques and is independent of the researcher's personal authority (Krippendorff, 2004). Six steps are usually followed in content analyses: unitizing, sampling/coding, data reduction, inferring conclusions, and narrating. What results from this phase is a set of concepts and sub-concepts that correspond to each one of the two questions that were asked.

3. Once the main concepts were identified from within the participants' responses, the concepts and their sub-concepts were articulated in tree diagrams, and thus, they become suitable to create networks of concepts.

4. The agreements among participants over a given concept or sub-concept were registered and formed the basis for the construction of networks of concepts: the nodes of networks represent the concepts or sub-concepts, and the links between nodes stand for the agreements among participants that some concepts (or sub-concepts) co-occurred in their responses. So, if two nodes are linked, it means the two corresponding concepts emerge together from within the content analysis, as referred to by the same person(s). Reversely, if two nodes are not connected, their concepts have not been mentioned together in any response by any participant.

5. The resulting maps help us to explore the context of the participants' words as well as their associations. Thus, the concept maps can be treated as network data, so methods of social network analysis (SNA) are applicable. For instance, once the networks were created per age and per question (also for all 36 participants), they were put in radial form to identify the central concepts that had the higher degree in the network and examine each node's information centrality.

3. Results

3.1. Indicative Responses

Some indicative responses (exact quotations) per question, per age group follow.

(i) Age group 20–30

Q_1: How do you feel when you endow the geographical space with personal preferences?

"Nostalgia… yes when I happen to go through the portals again; especially the ones that are not in my neighborhood I remember the phase and I like it. Exactly what I did before and after…As if it is my own creation and it is because I have given neutral buildings and neutral spaces a new personal meaning. Until now, the meaning these spaces had was either that I walked by them or went to work or that I went for a walk with friends. But now, they acquire an extra meaning for me".

Q_2: Do you think that the game offers opportunities for learning and teaching geography, building on your previous geographical knowledge?

"Undoubtedly yes, because it is like a game for elementary school, also for high school and even for high school (with a few modifications). As I teach at primary school, I am of the opinion that the geography lesson should be done outside, with the texts that appear, the maps in mountainous, lowland and coastal places, all over Greece. It would have a very positive effect on children to love geography…The answer is self-evident. Not only is it suitable for learning and teaching geography, it is also suitable because it is more lively and you participate so the lesson becomes more enjoyable if it's done this way".

(ii)Age group 30–40

Q_1: How do you feel when you endow the geographical space with personal preferences?

“This is a very nice feeling; I feel like the sites I hacked belong to me now. They also express my beliefs, that is, they express my ideology because they are places that belong to my ideological group. Both groups express ideology. That is, they are also places of ideological conquest…Everything I told you before. Acquisition, conquest and possession of spaces something like property but without papers”.

Q_2: Do you think that the game offers opportunities for learning and teaching geography, building on your previous geographical knowledge?

“Although, I do not think the game itself is suitable for teaching geography, what is offered here is the technology of augmented reality which opens new avenues in education. Elements of the game can be used in this direction, such as the map, but not the game itself”.

(iii) Age group 40–50

Q_1: How do you feel when you endow the geographical space with personal preferences?

“The memory always has nostalgia. And when I go through the streets in which I played and hacked portals, I remember the whole phase, I recall it quite a bit…I felt an extra familiarity with the spaces I visited and had a feeling that Ingress players have a secret that others do not know. I also thought that the spaces around me could be something else that I do not know so far and so, I became more interested in history. That is, I want to know what was there in the past, how it was changed, what happened next, and why what happened”.

Q_2: Do you think that the game offers opportunities for learning and teaching geography, building on your previous geographical knowledge?

“Technology, maps, texts are all offered and needed to be integrated into geography education. Certainly not the plot of the game! I think it is the modern way of teaching geography which (as usually happens) is not applied in today’s schools.

(iii) Age group 50–60

Q_1: How do you feel when you endow the geographical space with personal preferences?

“This game gives me the opportunity to feel something that was neutral is now mine. It is a sense of “ownership” of a building, a fountain, a feel of possession and intimacy together…I feel the space is mine, that I have enriched it with my thoughts, my feelings. I have left my mark and I can put myself in the shoes of the people who made what I see, whether they are just buildings or works of art”.

Q_2: Do you think that the game offers opportunities for learning and teaching geography, building on your previous geographical knowledge?

“Not only does it offer opportunities, but in my opinion, geography needs to be taught today with games like Ingress, because our children like technology, whether we like it or not. They learn easier and most importantly thank them.

It could be used for geographical training (with some modifications of course). This made me think about the texts he displays with information. And it responds even better to today’s children who have grown up with technology. Education needs radical change and Ingress combines education with pleasure”.

3.2. Content Analysis

The content analysis of the responses to Q_1 identified eight main concepts (table 2) and six main concepts for Q_2 (table 3).

Table 2

Table showing the concepts and sub-concepts of Q_1.

Concepts	Sub-Concepts (Level 1)	Sub-Concepts (Level 2)	Description
A			They are content because they contribute to the achievement of a goal of wider significance (the conquest of portals), which highlights a particular ideology (Resistance or Enlightenment).
B			They appreciate that the MAR game gives them an opportunity to conquer space by conquering portals.
C			They value that the MAR game gives them the chance to leave their own personal footprint on the real geographic space (even by using an alias).
D			They are pleased to feel they "possess" part of the geographic space, either considered as a personal possession or as a communal one.
	D_1		They feel the geographic space they played in belongs to them personally.
	D_2		They feel the geographic space they played in belongs to their team.
E			They feel nostalgic.
	E_1		They feel nostalgic for the streets they walked through while trying to reach the portals.
	E_2		They feel nostalgic for the stops they made at various points in the streets.
		E_{2a}	They feel nostalgic for the stops they made at landmarks (statues, fountains, squares, etc.).
		E_{2b}	They feel nostalgic for other points where they wandered before reaching the portals they conquered.
	E_3		They feel nostalgic for thinking and planning the way they followed to the portals.
F			They are enthusiastic that each portal expresses their team's ideology.
G			They consider portals as personal creations and, more specifically, as:
	G_1		Confirmation of an identity (either as Resistance or Enlightenment)
		G_{1a}	Personal
		G_{1b}	Or as part of the team
	G_2		Or as part of oneself with which they identify themselves.
H			They feel acquainted with the streets they walked through while searching for the portals.

Table 3
Table showing the concepts and sub-concepts of Q_2 (see text for explanation).

Concepts	Sub-Concepts (Level 1)	Sub-Concepts (Level 2)	Description
A			The participant considers augmented reality technology as useful for teaching and learning geography.
B			The participant suggests that the texts the game offers to the user are well suited to serve geographical education.
C			The participant holds the view that geography can be taught outdoors and the game Ingress contributes to this kind of education.
D			The participant considers that teaching geography with the aid of Ingress can be generalized to all levels of education.
E			The participant's perception is that Ingress is also useful for geographical education because it links geography with everyday life.
F			The participant believes that the game Ingress offers entirely new opportunities for education in geography, compared with his/her previous experiences of how they were taught geography in the past, and this evokes pleasant or unpleasant memories, specifically:
	F1		Pleasant memories which might be attributed to…
		F_{1a}	the fact that they liked the geography class while at school, or
		F_{1b}	the fact that they had had a good geography teacher at school.
	F2		Unpleasant memories which might be attributed to…
		F_{2a}	unsuitable or even bad teaching methods of teaching geography at school; or
		F_{2b}	an unsuitable/bad geography teacher at school.

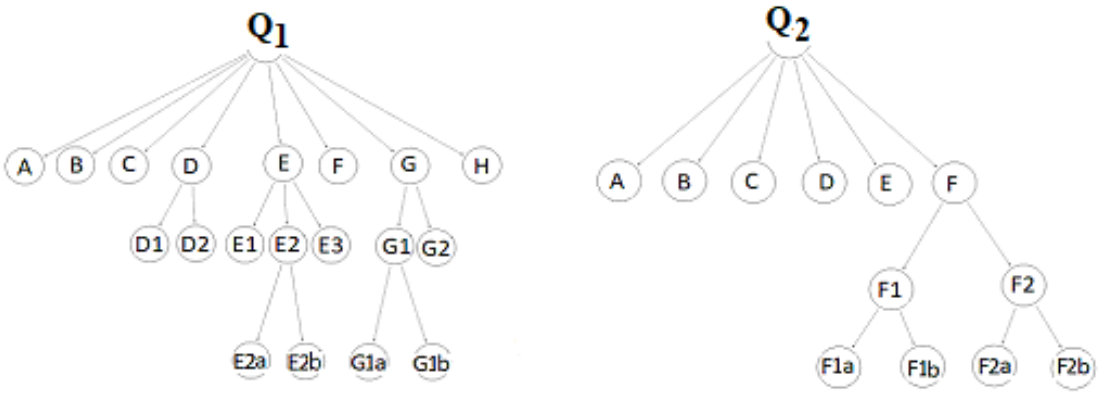
3.3. Concept Maps

The concept and sub-concepts are articulated in tree-like structures (figure 2). The structure of concepts of responses to Q_1 is significantly more complex than those for Q_2. From these tree-like concept maps, it is also possible to identify which concepts are more "critical" in each concept map: they are those that are modeled by a node that has the higher number of links. For question Q_1, it is the concept E (the users feel a kind of nostalgia, which is specified by sub-concepts of E) followed by

the concept G (the users consider portals as personal creations). In the case of question Q_2, the most critical node is F (the participants believe that the game Ingress offers entirely new opportunities for education in geography, compared with their previous experiences).

Figure 2

Concept maps (tree diagrams) showing the structure of the concepts and sub-concepts that have emerged from the content analysis of participants' responses to questions Q_1 and Q_2.



3.4. Network Representation of Concepts and Sub-Concepts

The agreements among participants for the concepts and sub-concepts of Q_1 per age group (figure 3) and Q_2 (figure 4) are presented in the form of networks, of which the nodes represent the concepts or sub-concepts and the edges (links) represent the agreements among participants (the occurrence of concepts).

3.5. Network Analysis

3.5.1. Node Centrality Analysis

A representation of the node degree of each concept (or sub-concept) in a way that highlights its centrality (per age group and per question) can also be created for Q_1 (figure 5) and for Q_2 (figure 6). These representations show the degree centrality of each concept or sub-concept in the network: the higher the degree of a concept, the more centrally located in the circle it is (and hence, the more inter-related it is with other concepts in the participants' responses).

Regarding the changes in a concept's node centrality in Q_1 as age progresses from 20 to 60, the following conclusions were drawn: personal footprint (C) → "personal footprint" (C) → "sights-texts" (E_{2a}) → "route planning" (E_3), "hack portals" (E_{2b}), "sights-texts" (E_{2a}). There are overlaps of preferred concepts/sub-concepts: in age groups 20–30 and 30–40 with "personal footprint" (C) as the central concept and another overlap in the age groups 40–50 and 50–60 with E_{2a} (sights-texts) as the central concept.

For Q_2, for the changing central concepts per age group the following conclusions were drawn: "augmented reality" (A) →"augmented reality" (A) →"augmented reality" (A), "texts" (B) →"augmented reality" (A), and so there was a persistent overlap of the participants' responses among all age groups. For all age groups, the central concept in Q_1 is "part of myself" (G_2), and the central concepts in Q_2 are "augmented reality" (A) and "texts" (B).

Yet, for all age groups (figure 7), the concept G_2 is central for Q_1 while concepts A and B are more so for Q_2.

Figure 3
*Network models of the co-occurrences of concepts and sub-concepts per age group: 20–30 (**a**), 30–40 (**b**), 40–50 (**c**), and 50–60 (**d**) for question Q_1.*

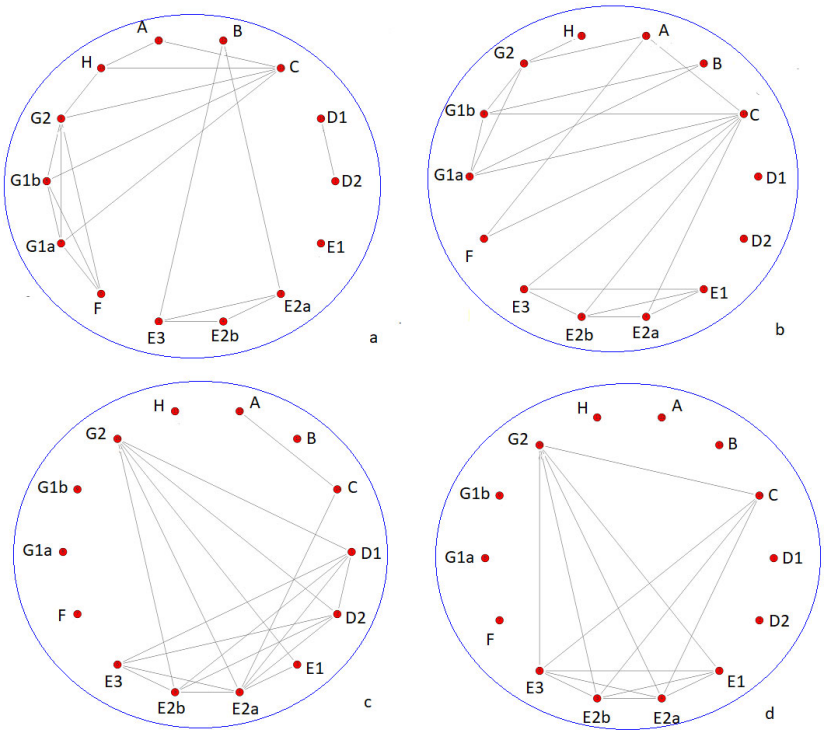


Figure 4
*Network models of the co-occurrences of concepts and sub-concepts per age group: 20–30 (**a**), 30–40 (**b**), 40–50 (**c**), and 50–60 (**d**) for question Q_2.*

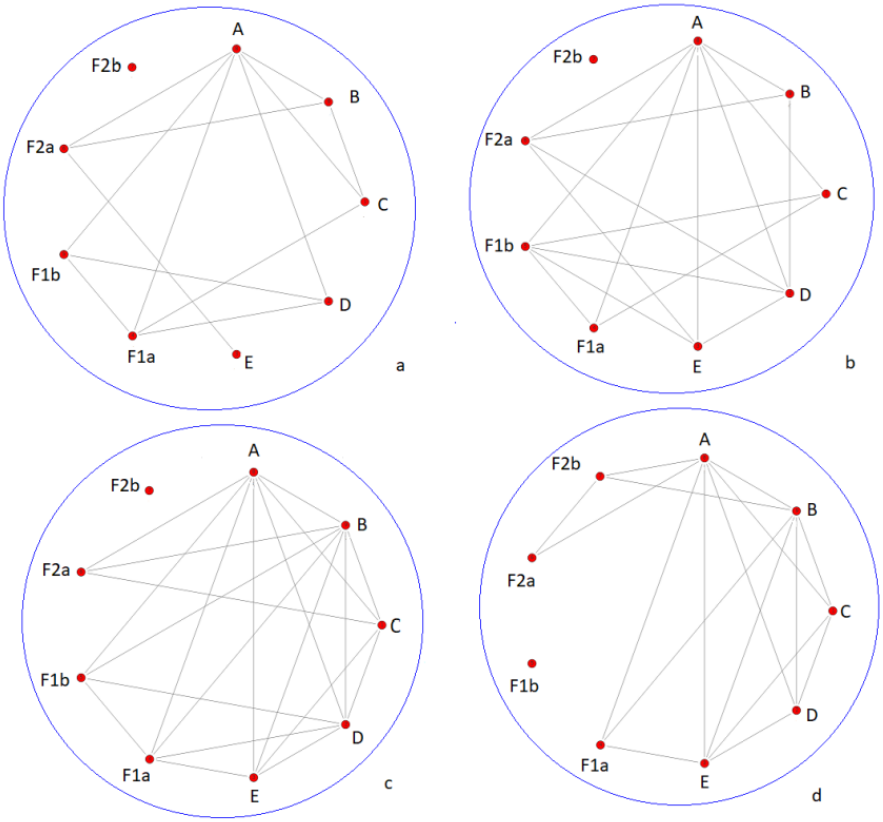


Figure 5

*Radial representation of the networks showing the node centrality of concepts and sub-concepts per age group: ages 20–30 (**a**), 30–40 (**b**), 40–50 (**c**), and 50–60 (**d**) for question Q_1.*

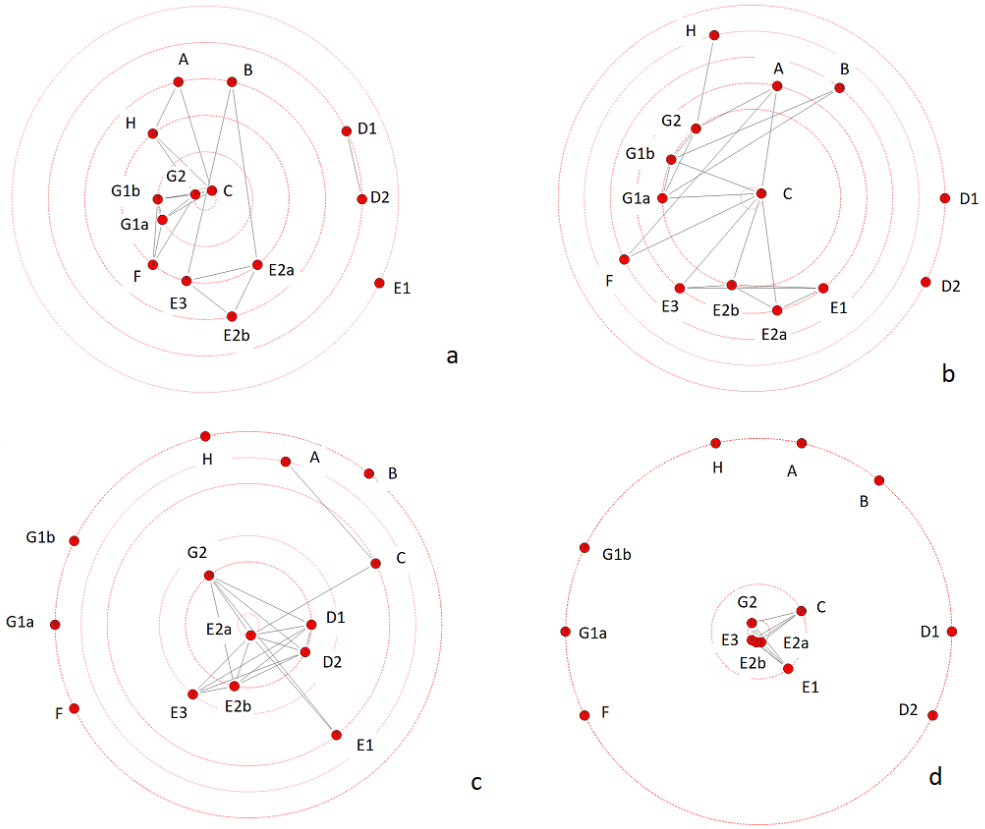


Figure 6

*Radial representation of the networks showing the node centrality of concepts and sub-concepts per age group: ages 20–30 (**a**), 30–40 (**b**), 40–50 (**c**), and 50–60 (**d**) for Q_2.*

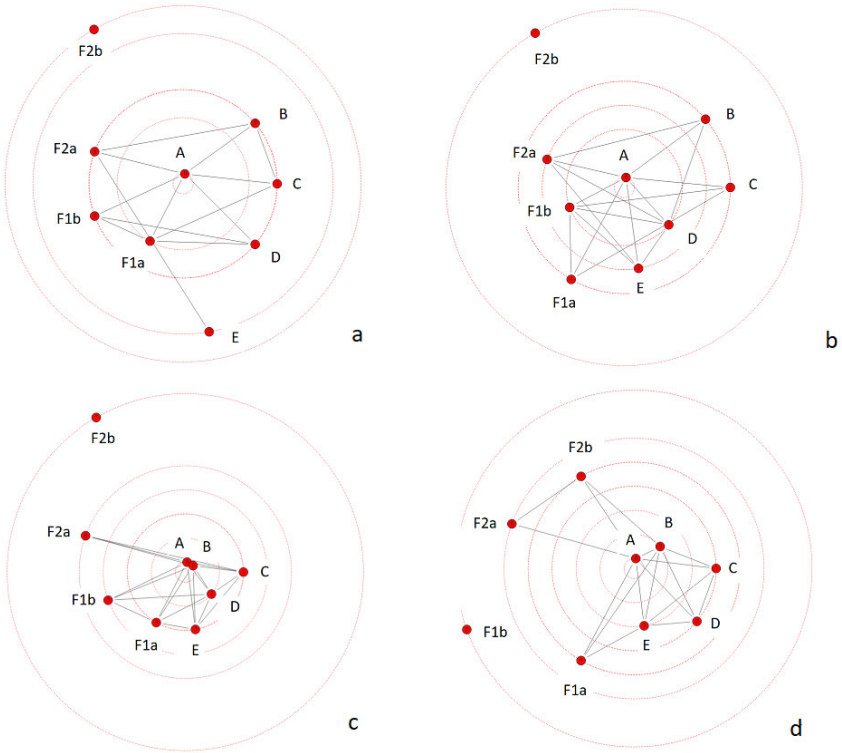
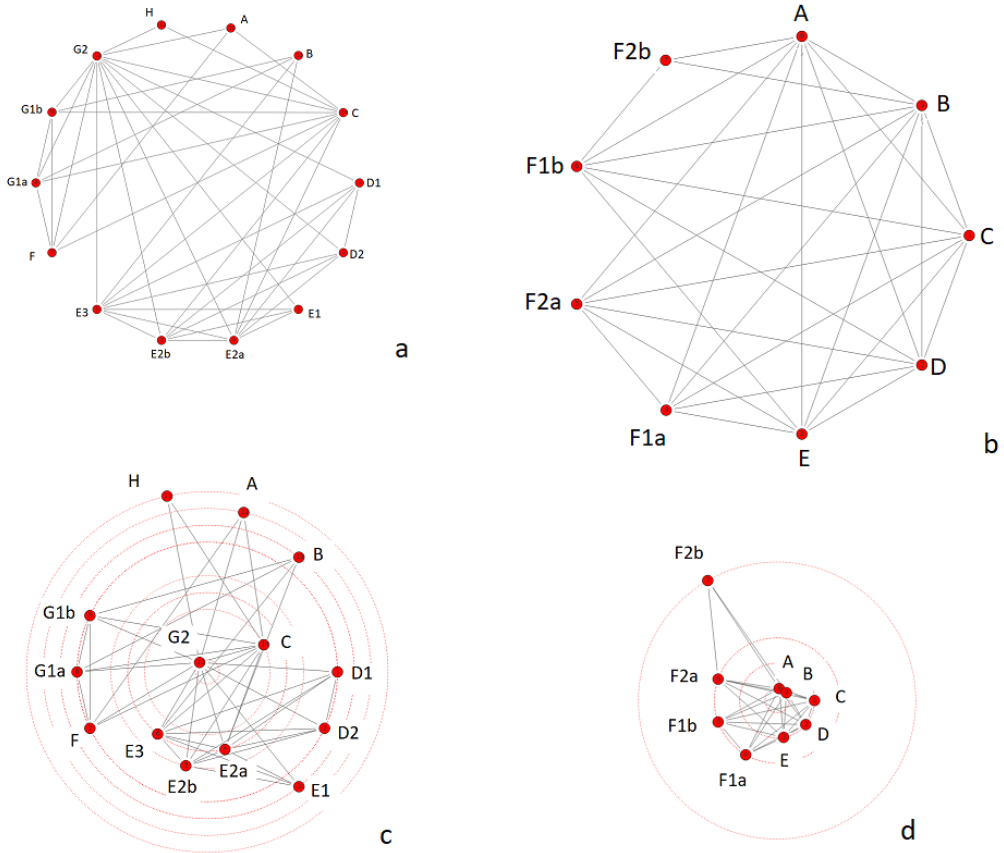


Figure 7

*Agreements among concepts for Q_1 (**a**) and Q_2 (**b**) and radial representations of the respective networks showing the central concepts in each case (**c**) for Q_1 and (**d**) for Q_2) for all participants (all age groups).*



In fact, some common constructivist-based teaching and learning strategies that can be employed in constructivist-oriented learning environments emerge from these patterns. Playing Ingress involves problem-solving activities, provides visual formats and interesting mental models, provides rich learning environments, involves cooperative or collaborative group learning, and promotes learning through exploration. Constructivism emphasizes problem-solving and inquiry-based learning rather than instructional sequences for learning of certain content skills. Constructivist approaches to assessment generally assume that by actively engaging in each of the stages of the inquiry process, learners will construct a meaningful understanding of the research experience. Using Ingress is perhaps one of the best ways to achieve this advanced kind of learning and to observe the emerging new mental constructs, even with respect to age differences.

3.5. Information Centrality of Concepts

The information centrality index (Stephenson and Zelen, 1989) measures the information flow through all paths between nodes (concepts and sub-concepts) weighted by strength of tie and distance. If there are i=1,2,3,...,n nodes in the network, then the information centrality (I_i) of node i is calculated from the centrality of the node i, with respect to all other nodes j and is defined by Stephenson and Zelen (1989):

$$I_i = \frac{n}{\sum_{j=1}^{n}\left(\frac{1}{I_{ij}}\right)}$$

The analysis of information centrality for all concepts and sub-concepts for both questions and per age group is shown in table 4.It can be verified that the information centrality of the two questions coincides with their radial representation.

Table 4

Highest values of the information centrality index for the concepts of questions Q_1 and Q_2.

	Age group				
Questions	**20–30**	**30–40**	**40–50**	**50–60**	**All**
Q_1	-	C = 1.601	E_{2a} = 1.721	E_{2a} = 3.428, E_{2b} = 3.428, E_3 = 3.428, G_2 = 3.428	G_2 = 3.573
Q_2	A = 1.789	A = 2.965	A = 3.621, B = 3.621	A = 2.845	A = 4.197, B = 4.197

4. Discussion

Our study showed how adult learners focus on different issues, which are ideally revealed through content analysis ("sub-concepts") using networks. These findings support the theory that adult learners have a fully developed self-concept as a result of successful completion of a social task and can recall information from long-term memory (Enesco, 1967). From the participants' responses to the questions, it is noticeable that Ingress highlights the fact that the game relates to constructivism. Adult students create their own subjective interpretations and meanings of what they have learned and they connect it to objective reality (Weerasinghe et al., 2019). AR games offer excellent opportunities for working with physical materials and concepts to construct new knowledge. Taking images, recording movies, and/or sound, editing, and integrating perceptual information across various sensory modalities with the user's environment in real time are examples of AR game-based constructivist activities. Previous studies (Huang, 2002; Isha & Rani, 2011; Ference & Vockell, 1994) confirm that educational methods fostering constructivism, when appropriately used, can enhance the adult learners' sense of belonging and can also foster their confidence and participation. According to Price (2002), constructivism is a way of teaching adults that allows them to absorb information by building meaningful, concrete concepts and long-term understandings of reality through active experience and critical reflection. Brown et al. (1989) stated that students should engage in problemsolving within contexts that are familiar and valuable to them. Learning, according to the constructivism theory of "situated learning", is not only the transmission of abstract and contextualized knowledge between individuals but also a social process that takes place within specified conditions such as activity, context, and culture (Anderson et al., 1996). The essential premise of "scaffolding" in learning, which is a distinguishing feature of this theory, is that tutors (or instructors) provide support as if they were creating a "scaffold" for the learners until they become able to assimilate the supplied new knowledge into their own cognitive frameworks. This could be the case with urban mobile games such as Ingress, in which the gameplay is affected by the sociocultural and material circumstances of the

unique urban location in which it is played, but, at the same time, the game creates a new shared understanding of urban surroundings (Moore, 2015).

Content analysis and concept maps may be a better way to find out what they believe about the subject they are studying. Since each investigation is unique and the outcomes are determined by the investigator's talents, insights, observational abilities, and style (Hoskins & Mariano, 2004), content analysis is more complex than quantitative analysis (Polit & Beck, 2004). One of the difficulties of content analysis is that it is very adaptable, and there is no one-size-fits-all approach. Researchers must figure out which combinations are best for their particular challenges (Weber, 1990), making the study process both challenging and exciting. In the literature on ICTs in education, this research method has received minimal attention. Backman and Kyngäs (1998) regarded the beginning of the categorization process as chaotic, because researchers must deal with and classify many seemingly unconnected pieces of knowledge. Another problem is that the narrative content is rarely ever "linear", and interview paragraphs can contain elements from numerous categories [Polit & Beck, 2004; Dey, 2003). For this reason, network models were used.

However, there were certain limitations to our research. One is the small number of game players, and another is that some of the findings of this study may be skewed by specific geographical settings (i.e., different cities, cityscapes within the same city) or by the demographics of the participants, necessitating additional research under different conditions and with different participants. In addition, various findings may be obtained using alternate classifications of the four age groups, although this particular classification in four classes has revealed certain similarities and variations among age groups. Content analysis, on the other hand, is an excellent tool for analyzing such qualitative data, particularly those produced from adult education research (Krippendorff, 2004).

Using concept maps in qualitative research presents several advantages for educational research. First, concept maps assist researchers to keep track of the meanings as they come out from within the interviews. When reading an interview transcript, it is easy to underestimate the depth of the concepts to which participants refer. The meanings associated to the concepts can be maintained thanks to the relationships represented by a concept map. Transcripts tend to represent spoken language in a linear format, whereas concept maps convey interview data in a hierarchical and interconnected manner. Graphical representations of concept maps are more akin to how we think and how we really communicate issues in an interview setting. In addition, concept maps assist us with minimizing data volume, illustrating links, and making (cross-group or other) comparisons easier. Possibly, the reader may find it difficult to distinguish which concepts are vital and which ones are secondary due to the intricacy of the interview that was carried out (Daley, 2004).

It is precisely for these reasons that the present research introduced the use of SNA, for the first time, in two fields simultaneously: in education and in MAR games. From this application, SNA turned out to be a particularly useful and innovative approach to education for the following reasons:

- The use of SNA to model concept maps opens up excellent opportunities to create visualizations of concepts and their inter-relationships.
- Quantitative aspects of SNA analysis (i.e., by using radial centrality and information centrality) provide suitable mechanisms to measure internal relationships in concept maps (in addition to visual inspection) that would not otherwise be visible (or even perceptible) at all.
- Using SNA enabled the classification of users' responses with respect to their interaction with the game and therefore was a fruitful approach for education that involves MAR games. Furthermore, with this method, it is shown how texts derived from interviews or from responses to open questions by different individuals can be analyzed both qualitatively and quantitatively with SNA.

While research findings relating to MAR games and videogames are only partially comparable, research in the latter type of games showed that younger adults up to35 years old are more likely to enjoy such games (Taddicken, 2014; Malik et al., 2020). However, the negativity of elder generations toward such games that has been identified in other research (Przybylski, 2014)may progressively disappear once they become more familiar with these games (Ferguson & Donnellan, 2017; Madrigal-Pana et al., 2019). This lack of negativity in attitudes of elder adults (52+) was also observed in previous research with Ingress (Sdravopoulou et al., 2021; Sdravopoulou et al., 2021).

5. Conclusions

This study examined the responses of 36 adult learners in using the location-based MAR game Ingress to the two following questions: (i) How do you feel when you endow the geographical space with personal preferences? and (ii) Do you think that the game offers opportunities for learning and teaching geography, building on your previous geographical knowledge? The results were analyzed by means of content analysis, concept maps, and social network analysis.

It was revealed that adult learners utilized some common constructivist-based learning strategies, confirming that AR games touch upon various learning theories, with the paradigm of constructivism being one of the central ones. The use of the MAR game Ingress enhanced active and authentic learning and created the opportunity for exploring experiential learner-centered learning more than the typical educator-centered learning. Another interesting point is that AR games can be applied to any learning environment, either indoors or outdoors.

By applying content analysis and concept maps as techniques of qualitative research in order to measure the users' responses to questions related to Ingress, it was found through central concepts that the space was part of themselves; by playing Ingress, they left their personal mark in the space, while the educational use of augmented reality was also emphasized. It was also found that there was a differentiation of the answers in question 1 between age groups with age groups agreeing in pairs, the first two (20–30) and (30–40) with the last two (40–50) and (50–60), while in question 2,there was an overlap in the responses of participants among age groups. In addition, methodologically, it is shown that content analysis and concept maps present the educational researcher with several advantages as they help to better visualize the links and subfields that emerge from interviews and participants' responses. Furthermore, these responses can best be analyzed both qualitatively and quantitatively by using methods of social network analysis.

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5. Discussion

5. Discussion

This study aimed at evaluating the usefulness of LBMAR games in adult education. Two sets of problems emerged and were tackled by adopting different approaches.

a) Educational:
   - Are there any age differences in the adults' perception and evaluation of these games? and
   - Which theories of adult education are relevant to the explanation of adult learning of LBMAR games?

b) Methodological:
   - Which type of AR technology is suitable for learning using smartphones? and
   - How to evaluate quantitatively and qualitatively the trainees' experience in their interaction with this category of games?

To address these problems this research brought forth new original methods and results, which did not exist in the hitherto available scientific literature.

Much like other research projects of this kind however, so this one has had its limitations in terms of resources, time and space. The research was carried out in one country only (Greece), so some of its findings would need corroboration from similar research from other countries or populations and this also applies to the particular socio-economic and educational characteristics of the participants of this research. Evidently, the sample used here should not be considered as a representative sample of *all possible* adult AR game users, if not for any other reason, because this study was conducted with non-users of "Ingress" only. But the sample size could not have been any larger than the one that was employed for the needs of this research. Expectedly, the duration of training before game was such that provided each user with adequate (neither minimal nor exhaustive) knowledge and skills to play the game. Although it was not possible to train each participant separately for longer than 4 hours, it was not necessary either. The age groups have been defined somewhat arbitrarily, but this is usual in educational and psychological research: it is common practice to define age groups that are meaningful for analysis (i.e. 20-30) instead of other ones that aren't (i.e. 23-37), although this does not also imply that the definition of these particular age groups would not affect their statistical or demographic characteristics. Besides this, the subjects of this research were persons only from Greece. Since countries differ in terms of lifestyle and culture, the results may also differ outside Greece. Future studies might enhance the generalization of the findings by investigating the use of "Ingress" by adult players in other countries. Should future researchers became able to examine more participants and explore variations between user groups (e.g. different age groups within the elderly group ands different socioeconomic groups), the findings would also become even more interesting, but this possibility is beyond the scope of the present study.

The three categories of AR (as defined by Chen & Tsai, 2012) are "marker-based AR", "markerless AR", and "location-based AR". As the analysis of the published scientific literature revealed (P1), all three of them are not equally suitable for adult education, as each one was found to have its own particular strengths and advantages, which make it more or less conducive to "naturalistic" uses or AR (including games). Plausibly, the more naturalistic an AR game is, the more appealing to adult users it's expected to be. As was suggested in tables 4 and 5 of P1, the "location-based AR" technologies are more relevant for learning and more

appropriate to use by means of smartphones. On the basis of this finding, they were identified as candidate technologies that are fit for further research in adult learning; it was for this reason that the smartphone-based location-based AR game "Ingress" was selected for the empirical part of this research. It is widely accepted (Cabiria, 2012; Dunleavy et al., 2009) that location-based AR learning environments can assist learning due to a combination of unique qualities, not only due to immersion, but also due to the fact that location-based AR settings differ from other technology-rich environments. This is because they use mobile and location-based interfaces while combining physical and digital spaces that result in blended spaces for learning (De Souza E Silva & Delacruz, 2006). In these settings, the prevailing characteristic of AR technologies (the feeling of immersion) is also prominent (Georgiou & Kyza, 2017) and, although experienced by using nothing more than a smartphone, the user of "Ingress" also feels immersed in the synthetic medium of augmented reality.

Addressing the methodological problems that arise in this research, it should first be noted that it is normally expected to present results about the trainees' interaction with the LBMAR game, both quantitatively and qualitatively. The quantitative part was carried out by devising suitable questionnaires and adopting a standard Likert-scale approach. By implementing a quantitative analysis of categories of learning according to Keller's "ARCS" model (Keller, 1983), it was possible to establish a link between the quantitative and the qualitative parts of the research. This is because the model's four discrete categories (attention, relevance, confidence, satisfaction) define qualitatively the most interesting areas of interaction between the trainee/user and the LBMAR game.

As has been repeatedly suggested in the literature of adult education however, adults most often express themselves not only by just stating their central idea plain and simple, but by also enriching it with variants, explanations, details, specifications or generalizations. A major problem therefore emerged, as to how to best analyse all these details and ramifications of thoughts and feelings from within a qualitative research. The problem becomes even more peculiar when some concepts and subconcepts appear to reiterate among the adult learners' words. To address this situation, three novel methods were suggested here, for first time ever in the literature: a) content analysis, b) Jaccard indices of agreements among the participants' responses and c) Social Networks Analysis. These tools have never been used before in research in adult education or in Human Computer Interaction (HCI). As it turns out, they can form new, well-founded and concrete methods for the analysis of concepts and sub-concepts in any content analysis, and particularly the content analysis that is derived from the responses of adult learners. Content analysis is the method of analyzing written, vocal, or visual communication messages (Cole, 1988). In the nineteenth century, it was first employed to analyze irrelevant to education texts, such as "hymns, newspaper and magazine articles, ads, and political speeches" (Harwood & Garry, 2003, p.15). As normally expected, content analysis should, at some point, become an indispensable tool for a wide range of research fields, such as journalism, political science, psychology, sociology, economics (Neundorf, 2002), because it is a systematic way of describing and characterizing occurrences of concepts and ideas expressed by people (Krippendorff, 1980; Downe-Wamboldt, 1992; Sandelowski, 1995). Researchers use it to distill words and to seek contextual similarities among words and sentences, and to derive some general categories comprising those words and contexts (Cavanagh, 1997). Content analysis has proven to be a very useful research method for inferring categories of concepts in this research. Since content analysis is a content-sensitive and flexible method (Harwood & Garry, 2003), aiding in both the analysis and the synthesis of meanings and ideas expressed by an interlocutor, it is an excellent tool in the hands of a researcher (Lederman, 1991; Downe-Wamboldt, 1992; Cavanagh, 1997). Moreover, what is

methodologically new here is that content analysis can be used for grouping information and for gaining new insights in adult learners' opinions about the LBMAR game they used. A researcher may choose whether to use the term "concept" or "category" (Kyngas & Vanhanen, 1999); the former was used within the context of this research. Content analysis is a reductive technique, aiding in the identification of few content categories (using non-overlapping codes) and particularly suited when one has to treat lengthy answers (Stemler, 2000).

Consequently, despite the fact that several quantitative techniques already existed for the analysis of one or two or few more responses on the same question, there was a gap in the case that concepts and sub-concepts reiterated in responses, but that was precisely the kind of data collected from this research. So some new method had to be devised, that would allow for the analysis of the responses of the participants in this research with "Ingress". This method was discovered from the field of Ecology and was the "Jaccard index". Furthermore, in the process of content analysis, it soon became evident that some concepts and sub-concepts were repeated frequently enough to enable oneself to derive some visual depiction, that is a "concept map"; then, methods to analyze such maps were discovered from the theory of Social Networks.

As concerns the Jaccard index, it has to be noticed that this index has a very widely used variant, the so called "Sørensen" or "Sørensen-Dice" index, which is also derived from Ecology (Dice, 1945; Sørensen, 1948). Its difference from the Jaccard index is that it assigns a double weight to the shared species:

$$S = \frac{2M_{11}}{M_{01} + M_{10} + 2M_{11}}$$

so this index might be used interchangeably, but the values it renders are different than those of the Jaccard index (J), since

$$S = \frac{2J}{J+1}$$

However, not this index was not used to analyze the agreements or disagreements in the concepts expressed in participants' responses and hence, future research may explore its applicability for inter-personal agreements and/or disagreements emerging from the content analysis of trainees' responses. Some of the clear advantages of the Jaccard index (Fletcher & Islam, 2018) are its conceptual simplicity, its computational simplicity (calculations are easy with it) and its interpretability (it can be interpreted in different ways, i.e. as "agreement" or "similarity" among things or ideas).

Social networks are represented by graphs with actors (people) as vertices and relationships as edges. They ranged in density from sparse to dense, depending on the number of concepts and subconcepts identified from the content analysis and on the number of agreements among respondents: the more a certain concept or subconcept they mentioned was linked to other ones, the denser the network. An intriguing class of networks, the "small-world networks" is common in social networks and has attracted the interest of many researchers due to their many locally dense clusters which connect a globally sparser network (Wasserman & Faust, 1994; Watts & Strogatz, 1998; Scott, 2000; Newman, 2003; Horn et al., 2004; Ghoniem et al., 2005; Henry et al., 2007). Despite their significance and relevance to social studies and other field of scientific enquiry, they were not useful a concept in the context of this research, because of the fact that SNA was mainly used here not to analyze persons and their relationships, but concepts and their relationships instead. Hence, much of

the work that has highlighted the importance of SNA in the analysis of i.e. social networking on the Internet, is irrelevant here, with the exception of the importance of "information centrality" which aided significantly in identifying the concepts that held central positions in the information structure of the concepts network. It is worth recalling nevertheless, that SNA mainly focuses on three key tasks: to identify more highly connected vertices that, due to their connections are able to form communities, or cohesive groups of actors; to identify central actors, and to analyze roles and positions of actors.

In the case of this research with "Ingress", it is a research novelty that once the primary concepts were discovered from the participants' responses, the concepts and their sub-concepts were articulated in tree diagrams, making them appropriate for creating concept networks. Thus, the agreements among participants over one particular concept or sub-concept were recorded and used to build networks of concepts: the nodes of networks represent the concepts or sub-concepts, and the links between nodes represented the participants' agreements that some concepts (or sub-concepts) co-occurred in their responses. When two nodes are linked, it signifies that the two matching concepts emerged together from the content analysis, as described by the same person(s). In contrast, if two nodes are not connected, no participant has stated their concepts together in any response.

As concerns the educational problems of this research, new findings came out from old and known theories. Theories of adult education (i.e. constructivism, humanism etc) and Keller's theory were known well before this research begun (Keller, 1983). But do they relate to the learning of LBMAR games and how? As this research has shown, not only they relate, in fact they are indispensable tools in understanding how adults interact with LBMAR games during the learning process. More precisely:

a) The ARCS model provides a unified framework for assessing an educational process. Aside of its methodological repercussions, it is highly valuable for understanding how adults learn and interact with LBMARs. This is because i) it is flexible and can be adjusted to each particular research that concerns either adult education or LBMAR and ii) it can serve as a guide to both quantitative research in adult education or LBMAR, i.e. as a framework to create questionnaires (as it was used here) or as a guide to qualitative research (by guiding the researchers which fields to address while devising their interviews or stating their open questions).

b) With respect to adult education theories, some interesting connections among prominent theories of adult education, the questions posed and the concepts derived from the responses should be mentioned. In fact, questions Q1, Q4 and Q5 of P3 addressed the cognitivist theories of adult education, as they focused on the ways adults acquire new knowledge and skills by playing "Ingress". Questions Q2 and Q3 of P3 and Q1 of P4 appealed to the humanistic theory of adult learning, by eliciting opinions that relate to the learners' ideals about society (Q2 of P3) and focusing on the exploration of the degree of their perceived self-improvement or accomplishment by playing the game (Q1 of P4 and Q2 of P3). Similarly, questions Q3, Q4 and Q5 of P3 related to behaviourist theories, since they examined behavioural ways of learning, while Q2 of P4 is intended to explore constructivist approaches in adult education.

Although constructivism re-emerges, time and again, as an important theme in geographical education, there is still deficient documentation of its paramount importance for the explanation of how adults build their knowledge upon previous knowledge and experiences. Constructivism emphasizes the importance of linking learning to real-life experiences and, according to Jonassen (1994, p.35), "constructivists emphasize the design of learning environments rather than instructional sequences". Further, as adult learners desire to acquire knowledge and

skills that they can apply in their daily lives or at work, educators should adjust their teaching material and methods to the experiences of adults, and these experiences are a significant resource to be exploited in the learning process (Brookfield, 1995; Bostock, 1998), even (in some cases) to the extent that adult learners participate in the course design (Huang, 2002). Obviously, more richer in experiences related to the subject of learning a person is, the more fruitful the constructivist approach will be. In the case of this research, all learners had attended courses of geography while at school. Whether and how a geography-oriented game such as "Ingress" was related to their previous experiences was a question to be examined with a constructivist approach in mind. In this research, it was shown that some particular concepts and sub-concepts are more central in understanding how adults build their experience and knowledge of Ingress on already existing intellectual, emotional or cognitive premises. Specifically, in question Q1 of P4, these concepts are the following: C (they value that the MAR game gives them the chance to leave their own personal footprint on the real geographic space even by using an alias), G (they consider portals as personal creations and, more specifically, G1 (confirmation of an identity either as "Resistance" or "Enlightenment"), G1a (personal) G1b (as part of the team) and G2 (as part of one which they identify themselves with) and all the concepts and subconcepts of question Q2.

With respect to the cognitive issues that are within the scope of the educational enquiry of this research, probably the most intriguing finding was that the opinions expressed by the elder groups of participants agreed more with those of the younger ones. This result came up in both the analysis of the responses by means of quantitative and qualitative research and was verified in two separate instances (it is unknown whether this finding might also emerge from other similar studies, or if it was simply a peculiarity that emerged from this sample population). In any case, it can be taken to suggest that those that already use these technologies for quite some time in their lives (e.g. those aged 30-50) are more likely to be less enthusiastic about a game with the qualities and characteristics of "Ingress" than younger adults or elder adults who find themselves more bewildered by it.

While this research used ARCS and content analysis with Jaccard similarity index and methods of SNA as the underlying methodological framework, other theories might also be relevant for similar contexts. For example, the "Theory of Planned Behavior" (Ajzen, 1985), or theories of "technology acceptance" (Davis, 1989; King & He, 2006; Venkatesh et al., 2012) might provide valuable insights in future research in this area.

However, applying the new methods that were used here for analysing the participants' responses in other researches in adult education is an avenue worth exploring in the future. This is particularly so in cases that the researchers have the impression (from the replies to the open questions) that the qualitative research with their adult learners produced concepts or subconcepts that are mentioned by several adult learners within the same research study (as was the case here). Also, it is interesting for future research to explore the usefulness of Jaccard indices and SNA methods in various domains where complex concepts and sub-concepts are used (i.e. consider the situation where some trainees are asked to comment on the multi-faceted concept "sustainable development").

6. Conclusions

6. Conclusions

The potential of Augmented Reality (AR) gaming technologies is highly regarded as suitable for a wide range of applications in education and Location-Based Mobile Augmented Reality (LBMAR) games constitute an important component of these technologies. To date, the bulk of the educational applications of LBMAR games had been confined almost exclusively to the education of children and youngsters (i.e. using "PokémonGo"), so it was hitherto almost entirely unknown whether such games might be any useful to applications in adult education. This need and deficit led to the realization of this research, which aimed at assessing the usefulness of a location-based mobile augmented reality (LBMAR) game (the game "Ingress" in this case) for adult education.

Firstly, the scientific literature was investigated in order to identify which one of the three types of Augmented Reality (marker-based, markeless, location-based) is most suitable for naturalistic applications of this technology. The results of the bibliographic search showed that different types of AR offer different alternatives and advantages for naturalistic approaches to AR, while also employing the use of different devices. Thus, marker-based AR promotes problem solving, fosters autonomy and improves collaboration, while markerless AR emphasizes the utilization of haptic technologies and enhances aesthetic experiences of users by being the most commonly type in wearable AR devices. Finally, location-based AR was found as more suitable for learning applications while also using more smartphones. These two key features of the location-based AR made it an ideal candidate technology for the education of adult users. Consequently, an empirical research was carried out to explore, both quantitatively and qualitatively, the opinions, attitudes, ideas and perceptions of adult users of a LBMAR game ("Ingress").

The empirical research tackled the problem of LBMAR games in adult education by considering it from within two different, yet overlapping, perspectives: educational (as to how adult users learn and how they interact with the game) and methodological (as to which methods are best suited to carry out such research projects).

As concerns the educational context, two major findings stand out: one relating to age differences and another relating to the relevance of some classic theories of adult education.

Age differences were repeatedly detected here. Certainly, it was not expected that all age groups of adult users would hold the same perceptions of and attitudes about the LBMAR game "Ingress. Unexpectedly however, as the findings revealed, in two out of the three empirical studies included in here, opinions of young people agreed more with those of elderly adults than with those of the intermediate age group.

With respect to the basic theories of adult education, it was also found that, to varying degrees, the education of adult users echoed some basic tenets of classic theories of adult learning: humanism, cognitivism, behaviorism and constructivism, and it appears very likely that LBMAR games intended for adult education should entail "humanistic" and "constructivist" approaches to learning; these will appeal to adult learners more and will make a game-based learning process more enticing.

With regard to the methodological context of this thesis, the participants answered both closed and open-ended questions and, through their responses, it was possible to single out their views and opinions on the use of the LBMAR game "Ingress". Consequently, entirely new methods were devised to investigate the quantitative and qualitative data that were collected. These methods were quantitative (by adjusting Keller's celebrated "ARCS" model for the purpose of this research) and qualitative (by means of content analysis, Jaccard similarity index and Social Network Analysis).

It was thus revealed that the ARCS motivation model can enable instructors of LBMAR games to identify the motivational needs of their adult trainees, to promote learning motivation and effectively improve user learning and performance. By demonstrating the applicability of the ARCS model in the teaching of one LBMAR game, it was therefore suggested that ARCS can be a useful model for evaluating education with augmented reality (AR) in adult education.

It was also shown that answers to open questions of educational research can be analyzed both qualitatively and quantitatively by means of Jaccard indices and methods of Social Networks Analysis, in order to derive quantitative assessments of agreements among the participants' responses. By using these two new methods for the content analysis of the participants' responses, methods were given for deriving quantitative data from the qualitative data (concepts and subconcepts) of the educational research. In the process of treating the qualitative data of answers to open questions, concept maps and networks were shown to be valuable tools offering visualizations not only of the concepts and their subdivision into subconcepts, but also of the links among them, as they emerged from the participants' responses.

All in all, aside of the field of educational sciences and technology, it is hoped that all those involved in content analysis (sociologists, psychologists etc) benefit from the new methods of analysis presented here, since they have a universal applicability, regardless of their particular field of application; analyzing many peoples' concepts and ideas by means of Jaccard indices and Social Network Analysis opens up a wide field of research.

And, as shown here, adults can learn, want to learn and enjoy using LBMAR technology (although, expectedly, with varying degrees of intensity and according to their age). Hence, considering all the findings of this thesis, it is suggested for educators of adult trainees of LBMAR games that they make their training more relevant to some of the tenets of some of the prominent theories of adult education (i.e. humanism and constructivism). Also, technologists might consider creating LBMAR games that are more naturalistic and suitable to adult users also, such as "Ingress". With these educational and technological premises in mind, adult users will become increasingly more interested in using LBMAR and LBMAR games in particular.

Information on the published papers

Report with the impact factor and quartile of the Journal Citation Reports

The following tables provide a brief description of the articles included in the thesis. These tables reflect: reference of the article and indexing of the journal. All studies have, therefore, article format with the following headings: abstract and keywords, theoretical introduction, participants, instruments, results of research, discussion and conclusions, and main limitations and references.

Study	**Reference**	**Indexing**	**Impact Factor**
P1	Sdravopoulou, K., Castillo, J. J. G., & González, J. M. M. (2021). Naturalistic approaches applied to AR technology: an evaluation. *Education and Information Technologies*, *26*(1), 683-697.	La revista está indexada en JCR, actualmente es Q1 (2020). Su índice de impacto en los últimos 5 años ha sido (JIF): 0.607 (2016), 0.403 (2017), 0.598 (2018), 0.782 (2019) y 0.919 (2020). Más información en https://www.scimagojr.com/journalsearch.php?q=144955&tip=sid&clean=0. Además, la Revista Education and Information Technologies está indexada en: ACM Digital Library, BFI List, CLOCKSS, CNKI, CNPIEC, Current Contents / Social & Behavioral Sciences, DBLP, Dimensions, EBSCO British Education Index, EBSCO Discovery Service, EBSCO Education Research Complete, EBSCO Education Source, ERIC, ERIH PLUS, Google Scholar, INSPEC, Japanese Science and Technology Agency (JST), Journal Citation Reports/Social Sciences Edition, Naver, Norwegian Register for Scientific Journals and Series, OCLC WorldCat Discovery Service, Portico, ProQuest-ExLibris Primo, ProQuest-ExLibris Summon, SCImago, SCOPUS, Social Science Citation Index, TD Net Discovery Service, UGC-CARE List (India).	0.919 (2020, Q1)

Study	Reference	Indexing	Impact Factor
P2	Sdravopoulou, K., Muñoz González, J. M., & Hidalgo-Ariza, M. D. (2021). Assessment of a location-based mobile augmented-reality game by adult users with the ARCS model. *Applied Sciences*, *11*(14), 6448.	La revista está indexada en JCR, actualmente es Q2 (2020). Su índice de impacto en los últimos 5 años ha sido (JIF): 1.679 (2016), 1.689 (2017), 2.217 (2018), 2.474 (2019) y 2.679 (2020). Más información en https://jcr.clarivate.com/jcr-jp/journal-profile?journal=APPL%20SCI-BASEL&year=2020&fromPage=%2Fjcr%2Fhome. Además, La Revista Applied Sciences está incluida en: Academic OneFile (Gale), AGRIS, CAPlus / SciFinder, China Academic Journals (CNKI), DOAJ, EBSCO, Inspec, J-Gate, ProQuest, Scopus, Web of Science, SCIE, Current Contents - Engineering, Computing & Technology, Current Contents - Physical, Chemical & Earth Sciences.	2.679 (2020, Q2)

Study	Reference	Indexing	Impact Factor
P3	Sdravopoulou, K., Muñoz González, J. M., & Hidalgo-Ariza, M. D. (2021). Educating Adults with a Location-Based Augmented Reality Game: A Content Analysis Approach. *Mathematics*, *9*(17), 2071.	La revista está indexada en JCR, actualmente es Q1 (2020). Su índice de impacto en los últimos 3 años ha sido (JIF): 1.105 (2018), 1.747 (2019) y 2.258 (2020). Más información en https://jcr.clarivate.com/jcr-jp/journal-profile?journal=MATHEMATICS-BASEL&year=2020&fromPage=%2Fjcr%2Fhome Además, la Revista Mathematics está incluida en: Academic OneFile (Gale),China Academic Journals (CNKI), DOAJ, EBSCO, J-Gate, ProQuest, Scopus, Web of Science, SCIE, Current Contents - Physical, Chemical & Earth Sciences y SJR.	2.258 (2020, Q1)

Study	Reference	Indexing	Impact Factor
P4	Sdravopoulou, K., Muñoz González, J. M., & Hidalgo-Ariza, M. D. (2021). Network Analysis for Learners' Concept Maps While Using Mobile Augmented Reality Gaming. *Applied Sciences*, *11*(21), 9929.	La revista está indexada en JCR, actualmente es Q2 (2020). Su índice de impacto en los últimos 5 años ha sido (JIF): 1.679 (2016), 1.689 (2017), 2.217 (2018), 2.474 (2019) y 2.679 (2020). Más información en https://jcr.clarivate.com/jcr-jp/journal-profile?journal=APPL%20SCI-BASEL&year=2020&fromPage=%2Fjcr%2Fhome. Además, La Revista Applied Sciences está incluida en: Academic OneFile (Gale), AGRIS, CAPlus / SciFinder, China Academic Journals (CNKI), DOAJ, EBSCO, Inspec, J-Gate, ProQuest, Scopus, Web of Science, SCIE, Current Contents - Engineering, Computing & Technology, Current Contents - Physical, Chemical & Earth Sciences.	2.679 (2020, Q2)

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