Building a Mobile AR Engagement Tool: Evaluation of Citizens Attitude Towards a Sustainable Future

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Abstract. Adopting a sustainable way of living in today's cities requires a high level of citizen empowerment, motivation, and engagement. The mobile Augmented Reality (AR) technology offers an accessible, inexpensive, and rich user experience that has the potential to lead towards this adoption. The widespread smartphones and tablets with unique features (e.g., embedded sensors, cameras, high-speed Internet, accessibility, and portability) provide powerful and ubiquitous platforms for supporting such applications. Mobile technology, and the easiness of immersing a mobile user in AR, impact the interaction of citizens with their environment. We leverage the deep penetration of mobile phones in urban environments and their advanced features to design and develop an AR citizen engagement tool. The tool is employed in a municipality and studied as means to foster citizen engagement in sustainable practices. The Technology Acceptance Model is used to study the acceptance of this application and the factors that may affect its adoption. In total, 127 end users were exposed to the prototype system that allowed 3D, audio, and 2D visualizations as well as interactions with them. Through a web-based survey, we assessed the factors and measures influencing the acceptance of technology and how they can be aligned with the characteristics of the contemporary urban settings and utilize the potentials offered by mobile AR technologies. Providing detailed information regarding the system design we expect that the results of this study will contribute to the discourse on the use of mobile AR as a tool for citizen engagement to guide the development of future efforts.

Keywords: Augmented reality · Citizen engagement · Mobile AR · Content management service · Technology acceptance model

1 Introduction

As the European Commission emphasizes [1], the transition towards a more sustainable future must bring together citizens in all their diversity and be supported by behavioral, social, and cultural changes. The complexity of the challenges that municipalities worldwide are facing, related to population growth and climate change, illustrates that

P. Bourdot et al. (Eds.): EuroXR 2021, LNCS 13105, pp. 109–125, 2021.
https://doi.org/10.1007/978-3-030-90739-6_7

the issues are not localized, and there must be partnership between governments and citizens, private and public sectors [2]. To ensure higher participation, the inclusion of citizens in public matters should be enhanced, and gender, social differences, and other heterogeneities should also be addressed.

New technologies and digital transformation play an essential role in the process to secure more active participation, reconfigure social relations and empower citizens, connect individuals and facilitate knowledge exchange across ever-widening spatialities [3]. Citizens empowered and committed transform from passive audience to interactors, and immersive technologies and interactive media are designed to generate such transformative experiences.

This paper aims to report on the design and development of a content management system (CMS) and a mobile AR app (CirculAR) and to study the factors influencing the acceptance of such a citizen engagement tool. We shed light on the interest and willingness to improve citizen engagement towards sustainable practices regarding the proper consumption of resources, better management of waste and pollution, and reuse of material via this tool. In the next section, we provide further background on engagement tools and the technology acceptance model. The methodology and AR system design is described in detail further ahead. The description of the system design aims to demonstrate the features that affected the acceptance of this technology and also to assist future development efforts. Finally, the evaluation of the application is described and discussed in the last section with recommendations for practice before concluding the article.

1.1 Citizen Engagement

Citizen engagement can be described as a particular type of user engagement and refers to how citizens participate in a community's life to improve conditions for others or help shape the community's future [4]. Direct engagement with relevant individuals or groups in society is the richest, most revealing, and valid source of knowledge about them. The process of citizen engagement involves many elements to be defined as efficient according to Olphert and Damodaran [4], and Information and communication technologies (ICT) have proved essential to foster an environment where the citizens become active participants. The critical success factors for achieving commitment and loyalty via citizen engagement include the perceived relevance of the shared knowledge, accessibility, usability, and value from participating in the process.

An effective engagement process should include the voices and needs of all citizens and increase their knowledge about a public issue, encouraging them to apply that knowledge and finally what they learned to improve their quality of life and the community [4, 5]. Creating opportunities for citizens to engage each other, and ensuring that these opportunities are regular and ongoing, contribute to the long-run success of these initiatives.

Over the past decade, media, technologies, software, and cultural practices have emerged that change how we experience the environment and interact with it. Various ICT tools, including websites, mobile solutions, and platforms, have been proposed to improve the understanding of public matters and engage citizens in a great variety [4]. Nevertheless, despite all efforts, such initiatives often fail since they are not inclusive.

They are designed for a specific target group, such as expert users and stakeholders, and they do not improve the participation of young people or are hard to use for seniors. Their content is often limited and very often not engaging. Finally, they are restrictive in terms of portability, usability, and accessibility; or they do not comply with a specific framework or measures [4, 5].

Olphert and Damodaran [4] presented evidence regarding the link of ICT technologies and citizen engagement to achieving broader citizen participation and increased social inclusion. Church [5], demonstrated the usefulness of methodologies encouraging participation from marginalized groups. An effective ICT solution should emphasize the inclusivity of the citizens, where past experiences, lack of knowledge, and cultural context do not limit involvement. Sections of the community that have not participated in the past and might not seem to be fertile ground for recruitment should be reached. An impactful engagement process is built upon diversity and equality. All members of a community need to participate in representing different viewpoints and interests, and it should be clear that everyone respectfully participates on an equal basis. The work of the community group needs to be open, transparent, and consistent. At the same time, the engagement process should create opportunities for learning and use or applying that knowledge further at a non-restrictive timeframe and pace. It is, therefore, apparent that engagement tools should be inclusive, accessible, transparent, support learning and long-run well-being to engage all citizens with their heterogeneities.

1.2 AR for Engagement

Given the immersive nature of AR technology, the extended use of smartphones, and the ability to couple them together with advanced location and camera settings, AR can be part of the citizen participatory process. AR offers experiences that enable the end users to move from observation to immersion which is often associated with the encouragement they experience in the digitally enhanced setting [6]. AR's immersive nature helps the audience see details believe in actions, and make connections between the events in the story and their own lives. Consequently, they are able to understand the positive impact of specific policies and changes [7]. Digital media are conveyed interactively, and physical experiences are recreated and enhanced with virtual content that enables participants to move beyond static images and gives them the freedom to choose any viewpoint and explore [8]. Mobile AR offers the advantage of portability and mobility to the end-user and accessibility and availability [9].

Due to the adaptable nature of the technology, mobile AR has the possibility of comforting the limitations that other engagement tools face. Up to our knowledge, a similar solution has not been developed to leverage advanced mobile functionalities and features (e.g., embedded sensors, cameras, 3D object manipulation, educational content, virtual assistant). Small scale projects have been proposed, but they have been examined in a narrow target group or fail to extract concrete results due to the lack of adherence to specific research frameworks or assessment models (e.g., [10]).

Acceptance of mobile AR technology is critical for the success and adoption of such a novel engagement tool. The assessment of the usability of mobile AR, allows researchers and designers to extract valuable information from end-users and improve the user experience [11]. The technology acceptance model (TAM) developed by Davis [12] is one of the most prominent models examining the acceptance of ICT tools with end-users. The model suggests that the actual use of technology is anticipated by behavioral intention, which is determined by the attitude towards using it, both being affected by the perceived ease of use and perceived usefulness. Perceived ease of use describes the extent to which an individual is able to use a technological system without effort, and perceived usefulness suggests an essential construct in swaying the adoption of new technologies as it may promote the confidence that utilizing a particular technological system may enhance performance [12].

Many empirical researchers have tested TAM, and the tools used with the model have proven to be of quality and to yield statistically reliable results [13]. TAM was used to analyze the use and acceptance of ICT by senior citizens and its comparison with the younger population. In their analysis, Guner and Acarturk [14], demonstrated the similarities of these two groups when using ICT services that they both consider helpful. Gefen and Staub, [15], tested the gender differences related to computer-based media and concluded with remarks regarding how females and males have different perceptions of use and usability. Burton-Jones and Hubona [16], studied the effect of age and educational level on the acceptance of ICT systems. The authors revealed that even though seniors had excess trouble navigating the ICT systems, this did not affect the perceived usefulness. Their study also demonstrated that if a task is not over-complicated, then the education level has only a minor impact on the perceived usefulness in favor of the users with higher education. Considering the multiple parameters affecting the acceptance of the engagement tool (such as age, education, gender, and tech-savviness), and the ability of TAM to reflect on such parameters, the TAM model is considered the most appropriate means to assess and explain the measures affecting the acceptance of the proposed mobile AR tool.

2 Research Hypothesis

As Davis [12] described, the perceived usefulness (PU), the perceived ease of use (PEoU), and attitude towards using (AU) affect the behavioral intention (BI) and, after that, the overall user acceptance of the technology. The following hypotheses were formulated and Fig. 1, provides a visualization of the research model.

H1: Perceived ease of use (PEoU) will positively influence users' attitude (AU) towards the AR engagement tool.
H2: Perceived Usefulness (PU) will positively influence users' attitude (AU) towards the AR engagement tool.
H3: Perceived Usefulness (PU) will positively influence users' behavioral intention (BI) to use of the AR engagement tool.
H4: Perceived Ease of Use (PEoU) will positively influence Perceived Usefulness (PU) of the AR engagement tool.
H5: Attitude towards use (AU) will positively influence users' behavioral intention (BI) to the AR engagement tool.

Since a significant role in adopting an engagement tool is inclusivity described by its ability to reach end-users regardless of any heterogeneities and educational background, the following research question was formulated.

Q: Is there any difference in the acceptance of the AR engagement tool depending on the tech-savviness, education level, gender, and age of the end-users?

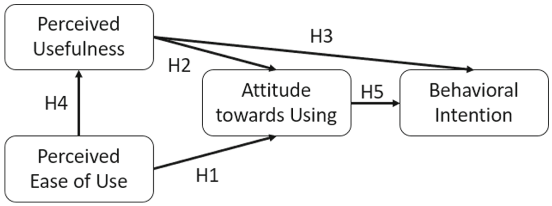

Fig. 1. Research model based on original TAM (Davis et al. [12]).

3 Methodology

3.1 Data Collection

A web survey was prepared and distributed to the citizens of the municipality of Karditsa in Greece, where end-users were exposed to the AR engagement tool via a video demonstrating its content, features, and interactive design, and filled out a questionnaire providing answers regarding their PEoU, PU, AU, and BI. Karditsa is an evolving peripheral town that belongs to the Municipality of Karditsa, Region of Thessaly – Central Greece. The survey was translated to the native language of the citizens (Greek) to avoid any language barriers or bias. All participants revealed information regarding their age, gender, education level, and tech-savviness. Since there were no missing responses and no patterns of incoherent answers observed, no questions were excluded from further analysis and all collected questionnaires were taken into account.

3.2 Measures

The questions in the web survey used the Likert Scale to demonstrate the agreement of the participant with statements ranging from “strongly agree” to “strongly disagree”. We chose a unipolar scale to measure the attribute of agreement in each statement that was treated as interval level (with intervals from 1 to 4). We chose four maturity levels in all measures for the Likert Scale to enable the user to form a clear opinion on each statement. As we ensured that all questions apply to our AR application user, we concluded that a specific user opinion is essential.

The questionnaire enclosed 14 items assessing the users’ PEoU, PU, AU, and BI, and four items assessing age, gender, education, and tech-savviness. The questions assessing PU, PEoU, AU and BI were adopted from literature [13–16]. Table 1 summarizes all TAM measures used in this study. Age, gender, and education, were assessed via drop-down predefined menus and tech-savviness was determined by the confidence of the user towards the use of smartphones and their features (such as camera and mobile apps), the frequency of playing mobile games, and their exposure to other AR technologies (Table 2).

Table 1. Summary of survey items assessing the TAM measures.

Construct	Measure
Attitude towards using	
AU1	The use of AR would make learning more interesting
AU2	I feel positive using the AR app
AU3	I believe using AR is a good idea
Perceived ease of use	
PEoU1	I believe it will be easy for me to use the AR app
PEoU2	The AR app appears intuitive to use
PEoU3	The AR app is not complex
PEoU4	The use of AR technology does not confuse me
PEoU5	The use of the AR app does not confuse me
Perceived usefulness	
PU1	I am satisfied with this experience as it seems novel
PU2	Using the app will help me learn factual information about CE
PU3	I find the AR app useful
Behavioral intention	
BI1	Spending time on AR seems worthwhile
BI2	I am satisfied with the type of the activity
BI3	I would recommend the AR app to my friends and family

Table 2. Summary of survey items assessing tech-savviness.

Item	Measure
Use of smartphones	Everyday/Sometimes per week/Sometimes per month/Never
Use of smartphone camera	
Playing mobile games	
Using AR	

4 System Design

4.1 System Architecture

The overall system architecture is designed to support two different users, the administrators of CMS, and the mobile application users of CirculAR. The administrators are considered the content owners. Their role is to produce and add content in the platform to create meaningful and educational experiences, so-called AR campaigns, that will be later enhanced with various gamification aspects and visualized by the mobile application end users.

The platform consists of two core components to support both the addition and editing of the content and its visualization and demonstration. The AR Content Management Service (CMS) is a web-based application that allows the administrators to create campaigns and add content to the platform, and the AR mobile application (CirculAR) is designed to provide the generated experiences to the end users. The design of the two AR components is presented in Fig. 2.

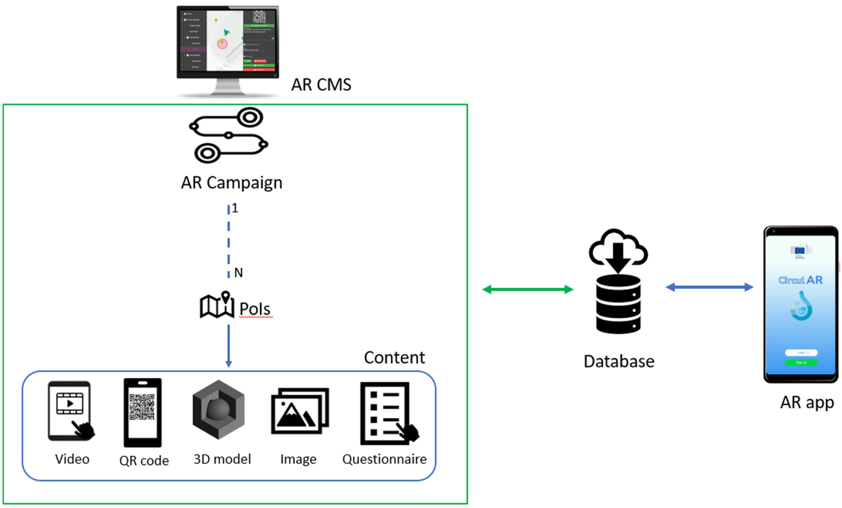

Fig. 2. The system design of the AR components. At the left side the AR CMS allows the administrator of the web-based application to create AR campaigns with Points of Interest (PoIs) on the map. The PoIs contain the content. Through the database that all information is stored, the users of the AR app access the AR content as soon as they reach the location of the PoIs.

The AR Content Management Service (CMS)

The CMS consists of two distinct parts; the back-end which stores the resources in the database and provides the APIs, and the front-end which retrieves resources through the APIs so as to display the CMS interface in the browser [17]. The CMS provides a user-friendly web interface, with a series of functionalities supporting the insertion of data to be displayed in the mobile AR app (Fig. 3).

Each AR campaign that enters the CMS contains all information necessary to create an engaging AR experience. Each campaign has an overall goal and objectives and consists of points of interest (PoIs). These PoIs signify a location or an area on the map containing all the media and educational content provided to the mobile user upon visiting it.

For each PoI, the CMS allows the administrators to perform the following actions:

- Add the location that represents the PoI.
- Add title and description in text format.
- Attach media content (image, video, and audio).
- Attach a 3D model.
- Create and add educational content (questionaries).
- Optionally generate a QR code to be scanned by the mobile app to visualize the previously added content.

The CMS front-end and the mobile app retrieve AR content from the database through REST API services [17]. The database is responsible for storing the content which is relevant with the campaigns (i.e. files, metadata, locations, etc.).

The CMS is developed using Vue.js [18] framework implementing the front-end interfaces. Figure 3 shows the user interface (UI) of the CMS. The back-end services are developed using Django [19] which is a high-level Python web framework that follows the model-template-views (MTV) architectural pattern. Regarding the storage requirements, PostgreSQL [20] is used as a relational database. Finally, for account security Keycloak [21] is used which implements the OAuth2 [22] protocol. During OAuth2 security integration, we consider the AR app and CMS front-end to be the clients. The CMS back-end is considered to be the resource server. NGINX [23] is deployed to increase security and hide information about the back-end servers so malicious clients cannot access them directly to exploit vulnerabilities and provide decryption of incoming requests and encryption of server responses.

In relation to the OAuth2 protocol and the actors involved, a resource server, in our case the CMS back-end, is holding data (such as the digital media and location of PoIs) that are owned by a resource owner, in our case the CMS administrator. Data can be accessed by the CMS and AR app users through the two clients (i.e.the CMS front-end and the AR app) which have been registered in Keycloak as trusty external applications. The resource owners (the CMS administrators) are the only users that can change the resources shown to the CirculAR users through their UIs (e.g. campaigns, content). The Authorization server, used in this study and presented in Fig. 4, keeps two different realms isolated (i.e., sets of users): the administrator handling the CMS front-end and the mobile AR app user of CirculAR. As presended in Fig. 4, the workflow is the following:

The user logs in to interact with the client (AR app or CMS front-end) and the client redirects the user to the token endpoint of the authorization server by providing the arguments redirect_uri, client_id and response_type. The authorization server checks whether the client is a trusty app registered in Keycloak. In this case it presents to the user's browser the login form where the user enters their credentials. If credentials are valid, the authorization server redirects the user back to the given redirect_uri along with the access token. This access token is signed with RS256 algorithm (i.e., an asymmetric

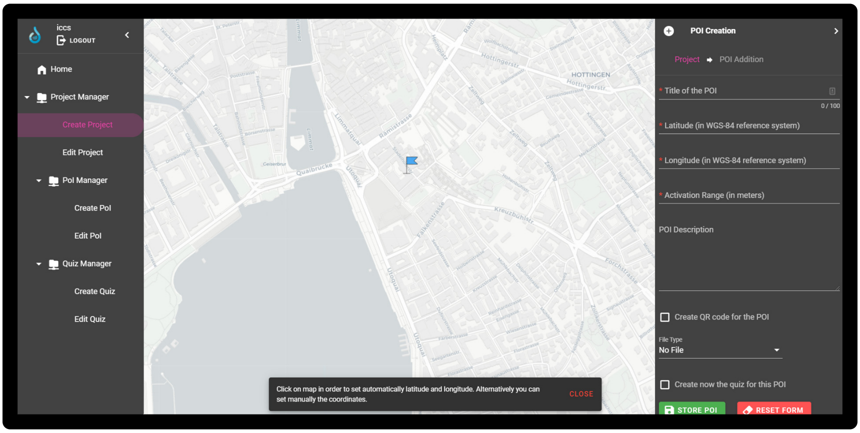

Fig. 3. The user interface (UI) of CMS. Using the functions of the left panel the administrator (user of CMS) can create an AR campaign through the project manager. For each campaign, the administrator decides the number of PoIs through the PoI manager. The Quiz manager allows the addition of educational content (questionaries and feedback). The functions at the right panel allow the customization of the content (including the description, digital media and 3D models, and quizzes) and determination of the location of the PoIs. The location can be added both manually and upon selection on the map.

algorithm that uses public/private key pair). The signature is generated with the private key which is kept secured in the authorization server. After the user is redirected back to a desired page of the client, the client catches the access token. This access token can be passed through the HTTP header in every request the client wants to make so as to retrieve resources. When a client (AR app or CMS front-end) asks for a resource, the CMS back-end which exposes the resources through services, validates the access token based on the public key provided previously by the authorization server).

Upon successful validation, the resource (i.e., PoI metadata, media file, etc.) is provided to the client and the client (AR app or CMS front-end) presents the retrieved resource to the user and updates the user interface accordingly.

The AR Mobile Application (CirculAR)

CirculAR was developed in the Unity game engine [24] using ARCore [25] and Mapbox [26]. The mobile app is compatible with Android smartphones and requires Global Positioning System (GPS) tracking as it supports both marker and location-based applications to overlay the digital data. The markers used in CirculAR to activate the AR experiences are QR codes generated by the CMS during the media attachment. The user of CirculAR should allow the use of the camera and location settings while using the app and be connected to the internet. Figure 5 shows four UIs of the AR app.

4.2 Features, Content and Gamification Mechanisms

Upon creating the AR campaigns from the CMS administrator and adding the respective content, the CirculAR allows the visualization of virtual content at specific locations

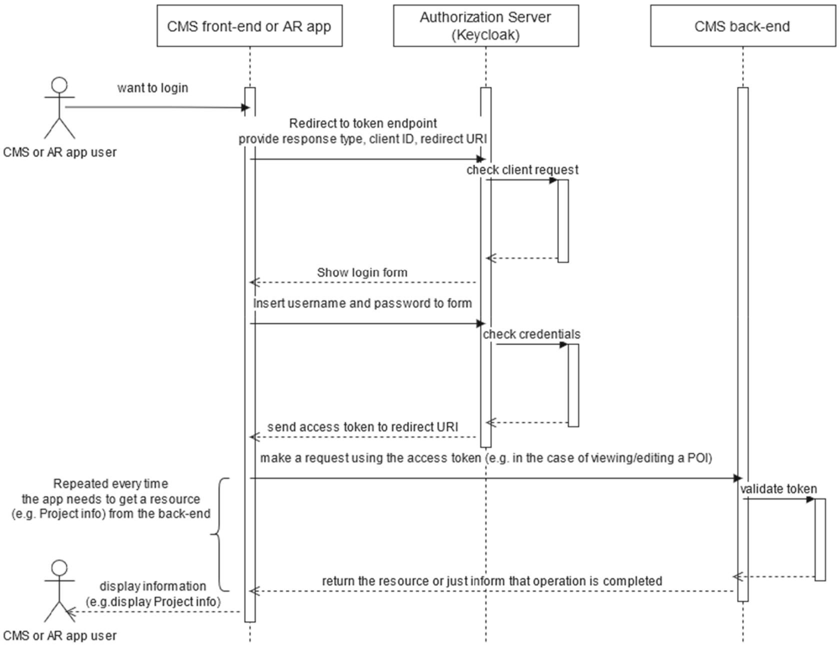

Fig. 4. The Authorization server (Keycloak) integrated in both CirculAR and CMS.

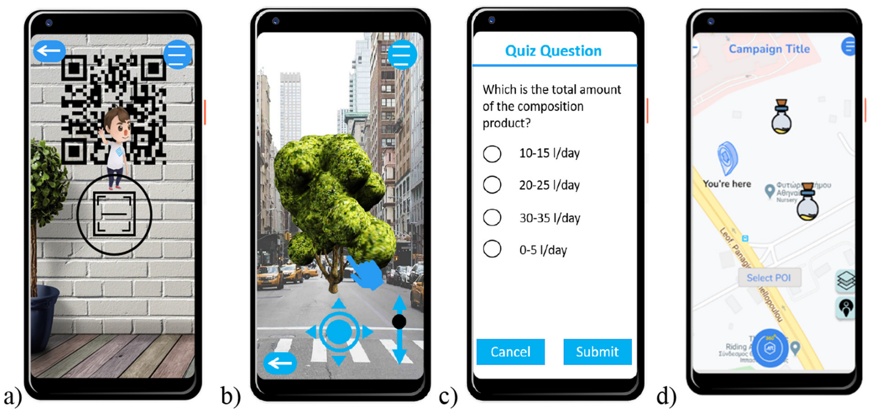

Fig. 5. a) The UI of CirculAR with an open camera setting, showing the virtual assistant. The user is prompted to scan the QR code and view the digital media. b) A UI with an open camera setting, demonstrating 3D content to the user. The media is activated based on the GPS location of the user. The hand indicates that the user is able to rotate the 3D virtual tree that overlays the physical surroundings. The arrows and cursor indicate the ability to move and rescale the virtual object around the physical surroundings. c) A UI with a quiz question that enables the user to test and validate their knowledge and understanding based on the virtual content they were previously exposed. d) The map with instructions navigating the user to the nearest AR experience from the AR campaign of their choice.

through the smartphone's camera. The app user signs up using email or Facebook credentials and can create a personalized profile (i.e., selection of avatar, username). The user then selects an AR campaign (an entity that contains PoIs, virtual experiences at specific locations) with the content of their interest from a list of available campaigns around them. Upon selecting the AR campaign, the mobile app navigates the user to the nearest virtual content, using GPS coordinates, through a map (see Fig. 5d). Upon reaching the location of the AR content, the smartphone's camera is activated, and the virtual content is visible, overlaying the physical world (see Fig. 5b). The virtual content is activated either automatically by reaching the location linked to the POI or by scanning the attached QR code (see Fig. 5a). Depending on the situation, a virtual assistant provides valuable tips and information to guide the user (see Fig. 5a).

The user of CirculAR can utilize finger gestures for object manipulation (both rotation and positioning) on the touch-based display of their smartphone [27]. The 3D object manipulation allows for six degrees of freedom (6DOF) which include 3DOF for object positioning (x, y, and z-axes) and 3DOF for object rotation (x, y, and z-axes). The input is given through arrows and cursors of the UI interface, and finger gestures able to manipulate on-screen objects (see Fig. 5b). The gamification elements include, among others, a scoring system, badges, and a leaderboard. Surveys and quiz questions embedded in the AR content challenge the user's understanding and provide feedback to enhance the learning effectiveness of the process [28] (see Fig. 5c). The quiz questions are embedded to the virtual content and typically link to the knowledge acquired through the visualization process. The gamification and learning elements of the mobile app ensure a captivating and fun yet educative and engaging experience [29].

5 Results

5.1 Participants

In total, 127 valid responses were collected by the web survey distributed to the citizens of Karditsa, Greece. The participants viewed the demo of CirculAR and answered all the questions mentioned in Tables 1 and 2. Additionally, they provided information regarding their demographics. Most of the participants are females (63%), but all share the same distribution in education levels, age, and tech-savviness. In all age groups the percentage of female participants fluctuate from 60 to 70%. Table 3 summarizes the demographics of the participants and tech-savviness.

5.2 Descriptive Statistics

Overall, we used descriptive statistics to summarize the data we collected, and Table 4 shows the mean value and standard deviation for the average values of all measures. According to [30] parametric tests can be used to analyze Likert scale responses and are recommended in cases where fewer concrete concepts are measured such as motivation and satisfaction. Following the next sections, we determine Cronbach alpha to provide evidence that the components of the scale are sufficiently intercorrelated and that the grouped items measure the underlying variable. The mean values closer to 1

Table 3. Summary of survey items.

	N	%
Sex		
Male	44	34,6
Female	80	63
Other	3	2,4
Age		
18–25	12	9,4
26–35	39	30,7
36–45	19	15
46–55	37	29,1
56–65	19	15
Education		
School	11	8,7
Bachelor	86	67,7
Masters	25	19,7
PhD	5	3,9
Other	0	0
Tech-savviness		
Use of smartphone	124	98
Use of camera	127	100
Mobile gaming	84	66.1
Use of AR	73	57,5
Total participants	127	

demonstrate the more robust agreement with the statements provided with the questionnaire and, after that, the higher tendency towards the technology acceptance measures. Participants demonstrate the highest tendency towards using the AR engagement tool, showing the lowest mean value and more minor standard deviation.

5.3 Validation of Measures

For all measures shown in Table 1 we also determined Cronbach's alpha. Cronbach's alpha (α) is a measure of internal consistency and reflects how closely related a set of items are as a group. Values of the parameter from 0.7 to 0.9 were considered "respectable" to "very good," and values above 0.9 were considered "excellent" [31]. Table 5 shows the alpha values (α) for all measures.

Principal component analysis (PCA) was then run with all measures to ensure that a single factor did not emerge. Correlations for the measures used in the study were

Table 4. Descriptive statistics for TAM measures.

Measure	Nr of items	Mean	SD
AU	3	1.609	0.584
PEoU	5	1.676	0.614
PU	3	1.614	0.593
BI	3	1.745	0.618

Table 5. Reliability estimates and intercorrelations for measures.

Measure	α	AU	PEoU	PU	BI
AU	0.83	1			
PEoU	0.94	0.753	1		
PU	0.89	0.842	0.730	1	
BI	0.84	0.854	0.721	0.849	1

calculated and shown in Table 3. They all appeared to be associated with each other, and all correlations were significant at the 0.01 level. The correlation between all measures had associations between 0.6 and 0.9. Overall, there was internal consistency among the four measures.

5.4 Hypotheses Testing

To verify our hypotheses (H1 to H5), we examined the relationships between pairs of the appropriate constructs defined in the research model using regression analysis. IBM SPSS statistics 23 software was used for the analysis. The results are presented in Table 6. The significance was less than the assumed significance level of 0.001 for all calculated regression values. Thus, for each of the hypotheses, we rejected the null hypothesis indicating the lack of dependence. The attitude towards using the AR engagement tool depends to a similar extent on the perceived ease of use (0.753) and perceived usefulness (0.842). The high relevance of PEoU and PU of the AR app with its acceptance might be since the users are willing to adopt a beneficial application that could make their lives convenient and guide them towards a more sustainable society. It has been proposed that to foster individual intention to use technology, a positive perception of the technology's usefulness is crucial [32]. Similarly, we accepted the H3, H4, and H5, as they demonstrated equally high values [33].

PEoU has a substantial influence on PU. To ensure that the bond remains strong, this may imply that proper user training is essential for improving users' perception of the usefulness of new technology to ensure high usage.

Table 6. The regression analysis for all measures in TAM model.

Hypothesis	Specification	Estimate	Significance
H1	PEoU → AT	0.753	$p < 0.001$
H2	PU → AT	0.842	$p < 0.001$
H3	PU → BI	0.849	$p < 0.001$
H4	PEoU → PU	0.730	$p < 0.001$
H5	AU → BI	0.854	$p < 0.001$

5.5 External Variables

We proceeded by further studying other factors affecting the TAM measures. The tech-savviness, age, education level, and gender of the users were identified as external variables affecting the acceptance of the technology. These factors were selected based on their effect on adopting similar citizen engagement tools [4, 5]. We analyzed the trends that these factors have on the TAM measures. Since these factors were assessed by either yes/no questions or a never-to-always scale, visual observations were considered more appropriate means of verification. Figure 6 summarizes our findings.

The education level of the participants demonstrated minimal effect on the TAM measures. A slight tendency towards higher behavioral intention appears among participants of higher education. Previous studies have reported that tools that demonstrate a high degree of relevance to their end-users appear to be more accepted, while the simplicity and easiness of navigating an ICT service may favor its acceptance [16]. End users of higher education levels may have been exposed to more information and communication tools.

Tech-savviness as demonstrated by the exposure of the participants to AR technology demonstrated slight variations in most TAM measures but overall, both users and non-AR-users achieved high scores in all measures (above 85%). As expected, participants who were previously exposed to AR technology appear to score higher compared to those who were seeing this type of technology for the first time. These differences should not be discouraging for non-AR users and further research should be contacted to investigate the progression in these values over further exposure. All differences among males and females appear to be less than 5%, proving that the AR engagement tool is positively accepted by both genders equally. This is a positive finding demonstrating that after 24 years, females have filled the gap in the acceptance of computer-based technologies demonstrated by Gefen and Staub [15].

A measure of higher acceptance appears to be among younger participants. While investigating other measures that may affect this tendency, both young and senior age groups demonstrate minor differences, below ~5%, in tech-savviness, education level, and gender variances. The demographics of our research study appear to be following the study performed by Guner and Acarturk [14]. Guner and Acarturk [15] reported that senior citizens prefer more ICT services that enable physical contact. Not only is the AR engagement tool a service to be used by each citizen by themselves, but the way it was presented to the participants (via video demonstration) may have enhanced

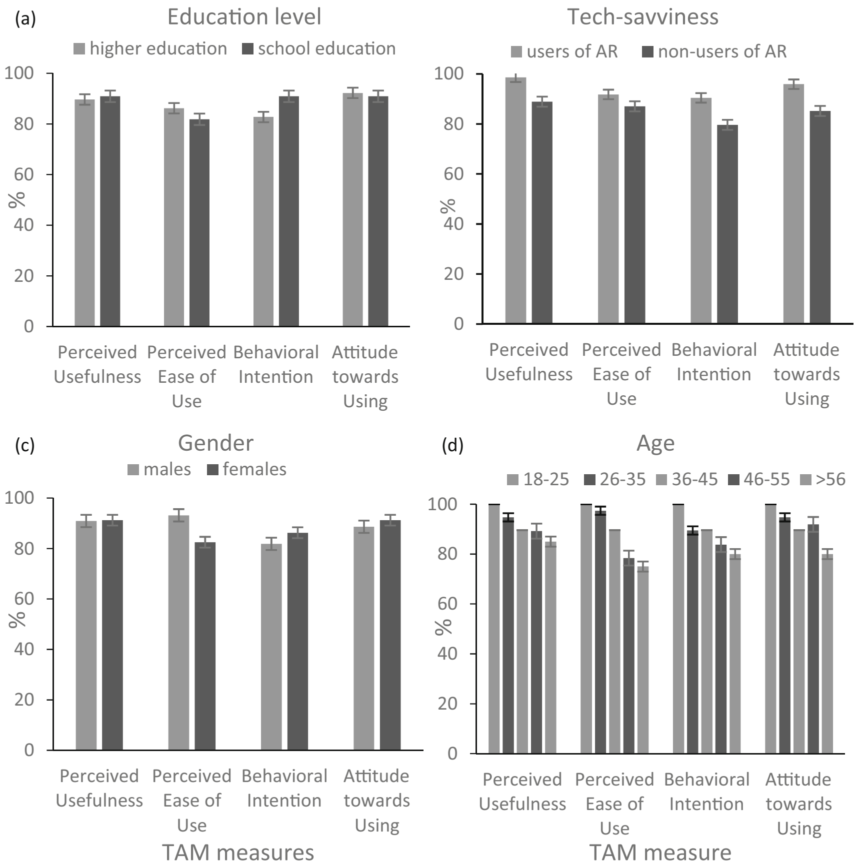

Fig. 6. The effects of (a) education level, (b) tech-savviness via exposure to AR, (c) gender, and (d) age of the participants on the TAM measures (mean agree or disagree statements ± SD, $p < 0.001$).

the perception that will not empower physical socializing among end-users. As Guner and Acarturk [14], also reported, the usefulness of ICT may positively influence the attitude of senior citizens toward use; however, it may not necessarily imply an intention to use ICT. In Fig. 6, perceived usefulness scored highest among all other measures of acceptance. Overall, answers remain consistent among age groups which agrees with previous research findings that both young and senior adults confirm TAM [14].

6 Conclusions

A mobile AR engagement tool has been designed and developed and its system design is presented to ensure that the features and content of such a tool are better understood and adopted in future efforts. Its use has been demonstrated to engage the citizens of a municipality in sustainable practices that benefit the consumption of resources, management of waste and pollution, and reuse of material. The purpose of this study was to demonstrate the system design of such a tool and determine whether TAM could legitimately be applied in an AR engagement tool by examining measures reported by literature to affect the acceptance of such technologies. Other factors, such as age, gender, education level, and tech-savviness, were also studied regarding their effect on accepting the AR tool.

This study supports the research hypotheses and confirms that TAM can be legitimately used to explain the users' adoption of an AR engagement tool. Followed by the research question, our main finding implies that the AR engagement tool fosters inclusivity in tech-savviness, gender, and education, while age may be a determining factor for accepting such a tool.

Funding. This research is based upon work supported by funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 776541 (nextGen circular water solutions).

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