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Faculty awareness of the economic and environmental benefits of augmented reality for sustainability in Saudi Arabian universities

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ABSTRACT

In recent decades, smart technology has been one of the major thought-provoking research subjects in the quest to meet the needs of society in ways that do not damage or deplete the environment and that conserve natural resources. Augmented reality is an emerging technology that blends three-dimensional virtual objects with reality. Technologies such as Augmented Reality can be useful tools to promote sustainable development in higher education in terms of various economic, social and environmental considerations. This paper aims to investigate faculty members' awareness of the potential benefits of incorporating Augmented Reality technology in Saudi Arabian universities in terms of its economic and environmental sustainability.

For this study, quantitative data was collected by means of a survey questionnaire where participants responded to statements on a five-point Likert scale that ranged from “totally agree” to “totally disagree”. The study was conducted with a sample comprising 228 academic and e-learning department staff from Saudi universities. The exploratory factor analysis technique was utilised to identify factors related to awareness of advantages of using Augmented Reality in education, particularly in relation to sustainability. Two factors were identified, namely environmental and economic factors. Study findings indicated that academic and e-learning department staff believe that the use of Augmented Reality in higher education has positional environmental and economic sustainability benefits. The findings from this study provide insights that will assist further studies regarding AR in the Gulf Cooperation Council countries.

1. Introduction

In response to rising concerns regarding environmental issues such as air pollution, global warming and climate change, an increasing number of organisations are taking steps to adopt environmental initiatives as part of their organisational ethos in order to protect the environment and reduce the consumption and waste of natural resources. Bettencourt and Kaur (2011) asserted that the concept of sustainable development (SD) at the global level is penetrating into businesses and governments' plans as well as the strategy and research programmes of Higher Education Institutions (HEIs). After discussing the role of Education for Sustainable Development (ESD) at Agenda 21, the 2nd World Summit on Sustainable Development in Johannesburg in 2002, and during the UN Decade of Education for Sustainable Development (UNESCO, 2005), the engagement of HEIs globally in sustainability has increased. In addition, in 2014 sustainability concern was reaffirmed in the Nagoya Declaration (UNESCO, 2014) which allows the goals set in Rio de Janeiro to be accomplished via the HEIs by encouraging the realignment of environmental, social, cultural, economic, and educational goals. Karatzoglou (2013) mentions that HEIs are recognised as a vital means of promoting sustainability initiatives. The integration of the concept of sustainability into the practices and missions of organisations has become a world concern in order to address sustainability issues (Stephens and Graham, 2010). More than 300 HEIs in the United States conducted campus sustainability evaluations over a five-year period, and several hundred others planned to do so (Elder, 2008). In some cases, sustainable innovations have been integrated in HE settings to provide better learning environments (Biberhofer et al., 2018). Other cases concentrated on students' perceptions about campus sustainability and sustainable development to identify the concern about the present/future implementation of sustainable practice and programs (Emanuel and Adams, 2011; Kagawa, 2007), or to

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examine students attitudes toward sustainability awareness (Lambrechts et al., 2018; Ng and Burke, 2010). In the developing countries, studies have been conducted to assess students' perception of factors promoting SD in higher education in China (Yuan and Zuo, 2013), the perceptions of Malaysian university students toward sustainability issues (Abd-Razak et al., 2011), and Saudi Arabian university students' "attitude and awareness of sustainability and green IT" (Albahlal et al., 2017). Albahlal et al.'s study was conducted among 1821 Saudi students using a questionnaire survey. Based on Albahlal et al.'s findings, there is a basic level of awareness among students regarding sustainability principles (e.g. wastage of resources, emissions pollution, and health hazards) and business opportunities related to green measures which are being applied in organisational practices (e.g. creation of new jobs and providing new opportunities).

However, questions regarding the role of smart technologies, in the context of the need to promote the development of an inclusive and sustainable society, arise when considering the integration of sustainable development in education (SDE). The growth of smart technologies has led to significant changes in education, teaching and learning methods. There are many emerging technologies that offer real environmental benefits and services which can be implemented in HEIs willing to take sustainability initiatives. One of the upcoming technologies that has yet to be widely exploited in the area of sustainability is Augmented Reality (AR), which can enhance interactions between humans and computers within intelligent environments in a more appealing and entertaining way with sustainability advantages (Elmirghani, 2017).

This study aims to identify faculty awareness of the economic and environmental benefits of AR for sustainability in Saudi Arabian universities. The paper has been organised as follows: firstly, it provides an overview of the background of sustainability in HEIs. Secondly, the use of smat technologies as SD is presented methods. This is followed by AR technologies and its benefits for sustainability section. Then the research questionnaire and the methodology adopted for this study are described. This is followed by the data analysis section. Lastly, the research findings and new insights are discussed.

2. Literature review

This section reviews the literature related to sustainability in higher education from different sources. In addition, the literature will be reviewed to discuss how Smart technologies (in general) have been used as SD approaches and explore the sustainability benefits of adopting AR technology in higher education.

2.1. Sustainability in higher education institutions

In 1978, the idea of sustainability in HEIs was initiated globally by the United Nations Educational, Scientific and Cultural Organization (UNESCO) (Wright, 2002). Numerous national and international declarations have promoted the notion that sustainability should be integrated into HEIs. The higher education community has increasingly acknowledged these declarations and a number of universities have authorised them (Wright, 2004). For instance, over 291 HEIs authorised the CRE–Copernicus Charter (CRE_Copernicus, 1994) after the Talloires Declaration of 1990 (UNESCO, 1990), which has over 275 signatories. HEIs, particularly universities, committed to these declarations by embracing sustainable development, integrating sustainability philosophies and generating frameworks that could be incorporated into their systems (Larrán Jorge et al., 2015; Lozano et al., 2015). In recent years, there has been a gradual change in institutions of higher education towards sustainable development (Wals, 2014). In addition, the United Nations Decade of ESD (DESD) (2005–2014) aimed "to integrate the principles and practices of ESD into all aspects of education and learning, to encourage changes in knowledge, values and attitudes, with the vision of enabling a more sustainable and just society for all" (Buckler and Creech, 2014, p. 9). The DESD was declared by UNESCO in the period 2005 to 2014 to emphasise the importance of incorporating sustainable development into the education system at all levels in order to raise awareness of sustainability. Education is the backbone of all nations, vital to developing their economy, policy and society. Ibidunni (2013) stated that "community services, research findings and teaching of the higher institutions should impart positively on the environment, people and the society" (p. 235). Reorienting education towards sustainability is educators' responsibility in order to serve the community by stressing the importance of judicious use of natural resources protection – with equally important concerns about economic, social, and political sustainability (Fien, 2001).

In regard to the field of higher education, ESD in the university context aims to integrate programmes and environmental initiatives that enable stakeholders to make a significant impact on sustainability, as well as changing the attitudes and values that stakeholders will need to manage with regard to future sustainability issues (Lambrechts, 2015). Universities can promote sustainability internally (via sustainability policy, environmental initiatives, campus sustainability, research and curricula) and externally (through their role in the region) (Dagiliūtė and Liobikienė, 2015). Different actions have been implemented by HEI such as transformation of their own tasks, research programme modification, integration of SD concepts into curricula, promotion of community participation, adoption of new methods of living on campuses and evaluation through sustainability reporting (Ceulemans et al., 2015).

For instance, an Australian university has raised students' awareness of their responsibility to contribute to sustainable development through the development and delivery of a new core unit that addresses the importance of sustainability and green information technology (Issa et al., 2014). Moreover, many more studies illustrate various universities' commitments to sustainability by promoting campus sustainability and greening (Geng et al., 2013), participation of teaching staff in education for sustainable development (Cebrián et al., 2015), and energy consumption and refurbishment (Huo and Yu, 2017; Yoshida et al., 2017). Another study was conducted by Isaias and Issa (2013) investigating the role of e-learning tools in fostering sustainability. The result confirmed that e-learning approcahes are more sustainable than traditional methods. However, there have been fewer studies regarding university staff awareness of sustainability that can be achieved by adopting smart technologies such as AR.

The ministry of education in Saudi Arabia (SA) is seeking to achieve its vision of SD by addressing and delivering efficiently in order to meet the present demands. They aim to accomplish and achieve a number of sustainable development focal points including society or human sustainability, economic sustainability, and environmental sustainability (Ministry of Education, 2018). Recently, green technology has been introduced into Saudi Arabian HEI. For instance, cloud computing was introduced by Alkhater et al. (2014) in Saudi Arabia as a green technology solution which could help to reduce costs and carbon emissions, and minimise energy consumption. Saudi Arabia Vision 2030 aims to have at least five Saudi universities competing with the world's top universities in international rankings. One of the main pillars of the Vision is young people aged under 25 who make up a large percentage of the current population (Khan, 2016). But in order to meet the needs of the present generation and provide a prosperous and sustainable future, there is a need to encourage mainstream sustainability, especially in universities.

2.2. Smart technologies as SD approaches

The 2030 Agenda for SD focuses on lifelong learning opportunities for all. The new goals expand on their predecessors, the Millennium Development Goals, by broadening and deepening the scope of the system's comprehensive quality education systems (UNESCO, 2015). UN Secretary-General, Antonio Guterres, at the close of the 2018 High-level Political Forum on Sustainable Development, stated that "technology has great potential to help deliver the SDGs, but it can also be at the root of exclusion and inequality. We need to harness the benefits of advanced technologies for all" (Barbara, 2018 n.p.). The diffusion of new technologies may be necessary to achieve the sustainable development goals, taking into account the need to make rapid progress towards achieving the goals by 2030. Over the past few years, the growth of smart technologies has led to significant changes in education, teaching and learning methods. Furthermore, sustainability issues can be addressed by adopting smart computing systems and educating professionals with advanced expertise in using these smart technologies in HEIs (Klimova et al., 2016). For instance, online/distance learning was found to have environmental benefits that may be able to lead to behavioural changes with subsequent positive environmental influences (Campbell and Campbell, 2011; Harizan et al., 2015). In addition, Lane et al. (2014) investigated the important social, economic and environmental impacts of Massive Online Open Courses (MOOCs). Their findings inspire confidence that MOOCs help to achieve lower carbon emissions and low energy consumption.

In line with the policy of sustainability demonstrated in the sustainable development goals of the UN, the link between sustainability and smart technologies was defined by placing community liveability at its centre. Smart technology plays an important role in the way it monitors, improves, manages and conserves materially relevant resources including energy, water, waste, and emissions. In HEIs, the roles of teachers and the educational environment have been changed by implementing various smart solutions. At the same time, these smart or "green" technologies promote the development of an inclusive and sustainable society. Green technology concerns the development of systems and equipment that will conserve natural resources, thereby mitigating negative impacts that human activities have on the environment (Agarwal et al., 2013). Therefore, the successful adoption of smart and green technologies is one means of achieving sustainable development, especially in educational institutions. Smart technologies such as AR applications have the potential to ensure sustainability and address the important pillars of the triple bottom line (TBL) that comprise three measurements in an institution: people, planet and profit.

2.3. Augmented reality and its benefits for sustainability

Azuma et al. (2001) defined AR as a system that augments the real world by using virtual objects via sensory input generated by computers, such as graphics, video, audio, and Global Positioning System (GPS) data. Information that cannot be obtained in the real environment can be provided via AR technology by combining a real-world environment with a virtual object to extend human senses. AR system use has been examined in some industries since the 1990s, such as healthcare, maintenance, architecture, entertainment, and more recently in education due to its ability to integrate virtual objects with real environments and bring a different type of understanding (Azuma, 1997; Broll et al., 2004; Hincapié et al., 2011; Pucer and Zvanut, 2016; Shin et al., 2010). Gradually, experiencng this technology is becoming easy and portable with flexibility to respond to user input. Some AR products have already been introduced to the market. The technology has been implemented on a slew of phone headsets such as Google Glass, Oculus Rift, Meta 2 headset, Microsoft HoloLens, CastAR, and in heads-up displays in car windshields, etc. Grande (2018) indicated that AR is a technology that develops the triple bottom line (TBL) by reducing costs and emissions caused by logistics. In addition, AR can help to achieve sustainable development through SDG 4 (UNESCO, 2017).

AR technologies have been mentioned in the literature several times as technologies that can lead to more sustainable built-environment outcomes and reduce the costs of structures, manufacturing, engineering, and education (Bacca et al., 2014; Carbonell Carrera and Bermejo Asensio, 2017; Ferrer-Torregrosa et al., 2015). A study was conducted in the U.K.'s Open University Design Innovation Group (DIG) investigating the economic benefits of virtual and online learning compared to conventional education. The results indicated that virtual and online learning consume up to 90 percent less energy (Roy et al., 2004). Cost reduction is one of the economic advantages of using AR technologies in the education domain as AR utilises virtual components of laboratory equipment and supplies instead of resources that are extremely expensive to buy (Wojciechowski and Cellary, 2013).

AR also promises to increase productivity, and the efficiency of teaching and learning practice in higher education. This will improve learning outcomes, thereby leading to the business efficiency of universities and enabling them to compete in the rankings of top world universities (Peddie, 2017). AR not only improves learning outcomes, but also makes teaching and learning more interesting and motivating (Cheng, 2017). The improvement in students' learning performance is another benefit of using an AR approach in teaching (Chiang et al., 2014). In higher education, several applications are available for the teaching of physics, mathematics, geometry, and electrical, chemical or mechanical engineering concepts. Therefore, the use of AR appears to offer potential cost savings to different sectors including higher education and ensure inclusive and equitable quality education.

Environmental sustainability involves issues surrounding energy and transport (e.g. electricity, solar, wind and thermal, oil, gas and coal), and resources such as computers, paper and ink. Sustainability encourages limiting the use of these resources and careful consideration of the disposal of any generated waste. As noted earlier, all HEIs are expected to reduce their environmental impacts and contribute to sustainable development (Tilbury, 2011). AR is an ideal technology in that it allows the user to experience the natural scene and at the same time not interfere with it in order to protect the environment. Usually, any type of arcitecture impacts on the environment via the building's footprint and waste management systems. AR is an innovative means of introducing sustainability into architecture. Professor Van Meeuwen believed that the impact of the building's footprint can be significantly reduced by not fully building it, and instead looking at the parts that we can turn into AR. For example, in the future, people from around the world will be able to meet in a conference room that is constructed in AR using Google Glass technology rather than being tangibly built, and have a meeting as though they are in the same room (Jewell, 2014). Further, integrating these technologies into learning processes and lifestyles can reduce pollution and make people safer (Roth, 2017). AR can be leveraged in engineering, design, and chemistry education by enabling students to visualise objects, test them, and eliminate them without causing any environmental damage or waste of resources.

Several studies (Chang et al., 2013; Walczak et al., 2006) have highlighted the relevance of AR applications and environmental education. They have indicated that AR will do more than that: there are a number of applications of AR environmental education which can be incorporated into education to facilitate teaching about environmental issues that cannot be seen with the naked eye, such as the simulation of potentially serious scenarios (e.g. nuclear pollution and chemical reactions).

Hammond and Churchman (2008) remind us that social sustainability is one of the key roles of the sustainability agenda in higher education. Quality of life is one of the social sustainability principles intended to ensure that community members are able to have a sense of wellbeing and the ability to succeed (Hammond and Churchman, 2008). In the teaching process, AR could decrease teachers' face-to-face lecture time, which can assist holistic human development and increase the productivity of the lecturers (Moro et al., 2017; Pan et al., 2017). A study conducted by Martin-Gutierrez et al. (2012) found an improvement in self-learning among engineering students who had used AR applications. Moreover, AR enables several students to learn and train simultaneously in the teacher's absence, thereby saving the teacher's time. In addition, the use of AR in some educational fields such as civil engineering helps to improve sustainable performance (Ayer et al., 2016). According to Wojciechowski and Cellary (2013), safety is another advantage of using AR applications in educational settings. For instance, potentially dangerous situations might be encountered by unskilled learners or teachers in an AR environment without causing any risk of harm to themselves or the waste of expensive equipment.

3. Research question and method

In this section, the objective and the research question will be stated, and a summary of the research methodology and approach will be presented.

This research has been conducted to determine the sustainability awareness of integrating innovative educational approaches such as AR into higher education in Saudi Arabia, particularly in universities. The research question in this study is: what is the level of awareness of the potential economic and environmental advantages of using AR in Saudi Arabia's higher education sector?

To answer the research question, the researcher opted to adopt a descriptive study design via quantitative research (a survey). The Qualtrics Survey platform was utilised to generate the online survey used for data collection. The Qualtrics platform is a web-based survey tool used to conduct survey research, evaluations and other data collection activities. The targeted population for this study were lecturers and e-learning staff in publicly funded universities in SA. The universities were selected as they planned to introduce AR technology. They were also selected because they are in the same geographical region and cater to many students. Furthermore, they offer multiple faculty options including medicine, engineering, and science, among others. Among Saudi universities, the medicine, science, and engineering programmes are highly regarded by both male and female students. In addition, they provide various teaching methods including computerised methods such as technologies and virtual learning environments, both of which are relevant to the study objectives and characteristics.

The study participants know and understand the characteristics of AR integration into higher education, as required for this study. The researcher visited each mentioned university in SA to collect the data. Each SA University has an ICT communication centre that contains the contact details of all academic staff. The researcher had already obtained Ethics Committee approvals from these universities to distribute the survey questionnaires, so was able to provide these universities' communication centres with recruitment material including the hyperlink to send it to the sample population. The researcher distributed the survey questionnaires with recruitment material, including the hyperlink, to the sample population. The total number of participants in this study was 228 from academic and e-learning department staff. The survey questionnaires were distributed on the 27th of August 2017. Follow-ups began a week after the survey was sent. Unfortunately, follow-ups do not always help to increase the response rate (Baruch and Holtom, 2008). After three months with three follow-ups, the number of responses from academic and e-learning staff was still quite low. In order to increase the number, the survey was also distributed to potential respondents via email, WhatsApp, LinkedIn, Twitter, and Facebook. Five months later, the researcher was able to acquire an additional number of responses from academic and e-learning staff. Facebook and WhatsApp were more effective than emails in increasing the number of responses.

Participants were asked to indicate their responses regarding the potential sustainability of integrating AR as a learning method on a five-point Likert scale ranging from 1 for "strongly disagree" to 5 for "strongly agree". The Likert scale was used to minimise respondent uncertainty and maximise response quality (Revilla et al., 2014; Devlin et al., 1993). Several advantages of using an online survey have been identified by Issa (2013); these include low cost, time-saving efficiency and ease of distribution. Moreover, it enables the researcher to fully control the data collection process; different survey formats are available; the researcher can easily remind respondents to answer the questionnaire, and can thank them for their participation (Issa, 2013). The online survey consisted of four sections. In the first section which consisted of closed-ended questions, respondents were asked to provide demographic information comprising age, gender, computer experience, and level of interest in technology. In the second section, scaled-response questions were asked to ascertain respondents' opinions about the benefits, to sustainability, of using AR in higher education, and to determine their attitude toward using AR technology as a teaching and learning tool. Respondents were asked to indicate their level of agreement/disagreement with each statement on a five-point Likert scale.

Three subsections were included in the final section of the survey in order to identify factors that could influence the adoption of AR as a teaching and learning method in the Saudi Arabian context. These subsections consisted of rating statements to measure contextual factors such as religious views, sociocultural reactions, and beliefs that might impact on the effective use of AR in SA universities. Normative belief dimensions in this study were adopted from Marcinkiewicz and Regstad (1996). The questions were improved by adding the dean of the college, head of the department, and lecturers as "significant others" in addition to students, as used in Marcinkiewicz's questionnaire. The survey measurements and questions were derived from previous studies and adapted by the researcher.

A pilot test was conducted before conducting the main survey in order to ensure the suitability and reliability of the survey questions and structure. An adequate number of experts, lecturers and academics in the technology and education domain were asked to provide feedback on the questionnaire. The questionnaire was also reviewed and pre-tested by PhD supervisors to ensure face validity. Several well-conceived changes were made to the questionnaire in this study based on feedback received from the pilot test respondents and experts. These changes included breaking down longer questions into two parts for reasons of clarity, and the rewording of some questions to remove ambiguity or uncertainty. The final version of the survey reflected all the changes.

The Statistical Package for the Social Sciences IBM SPSS Statistics (version 25) was utilised to analyse the data by applying exploratory factor analysis (EFA) for statistical testing.

Table 1
Staff demographics.

Job Title	Gender		
	Male	Female	Total
Lecturers and academic members	89 (61.0%)	57 (39.0%)	146
e-learning department staff	45 (54.9%)	37 (45.1%)	82

This paper will be limited to discussing only one section of the survey, that which sought the respondents' perspectives regarding sustainability awareness of using AR technology in Saudi universities.

4. Participants

The sample population for this study comprised 228 teachers (academics) and e-learning department staff from universities in Saudi Arabia. These participants know and understand the characteristics of AR integration in higher education and were therefore appropriate for this research. Ritchie et al. (2013, p. 113) indicated that the two aims of selecting a sample are "to ensure that all the key constituencies of relevance to the subject matter are covered, and within each of the criteria there is enough diversity included so that the impact of the characteristic concerned can be explored". The participants were selected on the basis that AR technology will be introduced in the education context.

The academic staff participants in the survey numbered 146, of whom 82 were e-learning department staff members. The majority (89 or 61.0%) of the academic participant respondents were male, whereas the number of responses from academic female participants was 57, or 39.0%. In addition, over half (54.9%) of the e-learning staff sample were male, while the number of e-learning department staff responses from female participants was 37 (45.1%). Table 1 summarises the demographics of the staff sample.

The majority (47 or 32.2%) of the academic participants (lecturers) were aged between 34 and 38 years. About 12 (8.2%) of the academic respondents were aged between 24 and 28 years. Twenty-nine of the lecturers were in the 29–33 years age category. Thirty-four of the 146 respondents (23.3%) were in the 39 to 44 age group. Only 22 lecturers were aged 45 years and above. Fig. 1 below shows the ages of respondents.

As mentioned previously, the total number of e-learning department staff participants was 82. The largest group of the 82 (36.6%) participants from the e-learning department were aged between 34 and 38 years. Nine participants were aged between 24 and 28 years, followed by the 29–33-year age group (28.0%). Sixteen of the e-learning department staff participants were aged between 39 and 44. Only 4.9% of the e-learning staff participants were between the ages of 45 and 50. Fig. 2 below shows the ages of e-learning department staff.

Lecturers were asked to indicate the extent to which they made use of technology in their professional activities. The results showed that most of the participants (95.2%) of both genders indicated a medium to high level of technology use for teaching and learning purposes, whereas only 4.79% had a low level of technology use for their professional activities. Fig. 3 below presents the frequencies of using technology in education by academic staff.

5. Data analysis and results

This section presents the results of the analysis of academic and e-learning staff survey data. The Statistical Package for the Social Sciences (SPSS) was utilised to analyse the collected data using several statistical tests and methods. Initially, accuracy, outliers, missing values, and normality of instrument items were examined for data entry. Then, descriptive statistics analysis was conducted to obtain the basic features of the collected data. Next, EFA was applied to determine the sustainability factors related to the use of AR in Saudi higher education. The findings are presented later in more detail.

5.1. Descriptive statistics of the sustainability awareness of AR use in higher education

Academic and e-learning staff awareness about the sustainability advantages of AR technology were measured in order to answer the research question. They were asked to rate their level of agreement with eight statements. A five-point Likert-type scale was used to measure respondents' opinions regarding sustainability awareness of using AR in higher education: 1 = SD (Strongly Disagree), 2 = D (Somewhat Disagree), 3 = N (Neither Agree nor Disagree), 4 = A (Somewhat Agree), and 5 = SA (Strongly Agree). Statistical analysis was applied to the data by calculating the means of the statements, median and standard deviations to indicate participants' responses.

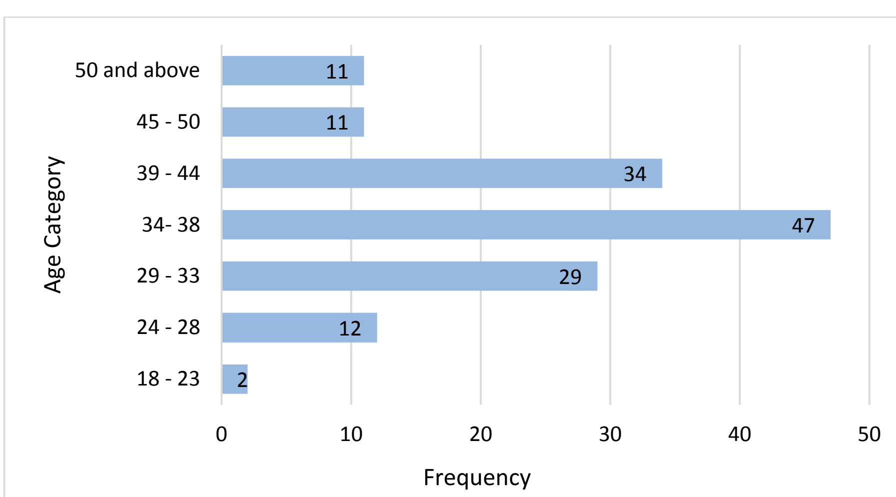

Fig. 1. Ages of lecturers and academics.

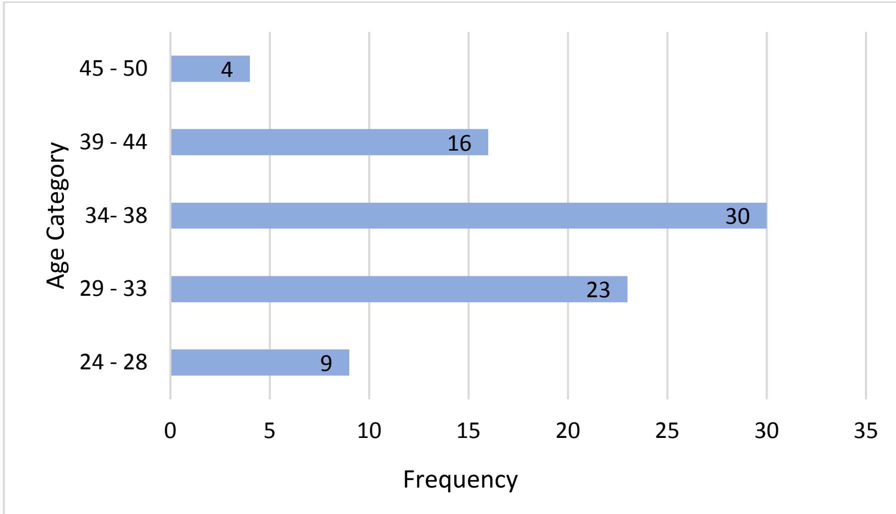

Fig. 2. Ages of e-learning department staff.

The overall sustainability awareness of academic members and e-learning staff regarding AR in SA universities was high (M = 3.5, SD = 1.0). As can be seen from the table below, the most frequently mentioned factors related to sustainability awareness of AR use were numbers 2, 5, 4, 3, 6 respectively. Dimension 2, "*AR can reduce raw materials (printing books, etc.)*" (M = 4.03, SD = 0.862), dimension 5, "*AR can reduce consumption and waste of resources*" (M = 3.70, SD = 0.984), dimension 4, "*AR can reduce a teacher's face-to-face lecture time*" (M = 3.62, SD = 1.061), dimension 3, "*AR can reduce ICT equipment used in learning such as PCs, devices and labs*" (M = 3.54, SD = 1.067), and dimension 6, "*AR can reduce air pollution*" (M = 3.39, SD = 1.016). The least frequently indicated sustainability awareness of AR were dimension numbers 1 and 7. Dimension 1, "*AR can reduce energy*" (M = 3.32, SD = 1.009), and dimension 7, "*AR can reduce global climate warming*" (M = 3.27, SD = 0.987). The results obtained from the preliminary analysis of the data regarding the sustainability awareness of using AR in Saudi higher education are summarised in Table 2 below.

5.2. Exploratory factor analysis (EFA)

To explore the factor structure between survey dimensions and to identify dimensions related to sustainability awareness of using AR in education, EFA analysis was also conducted. Section two in the survey was related to academic and e-learning staff sustainability awareness of using AR in Saudi Arabian universities. EFA was established and confirmed factorability with a KMO value of 0.813, which is above 0.7, and Bartlett's test is significant ($p < .001$) (see Table 3). Therefore, factor analysis was appropriate for this section and factor dimension correlations were mostly >0.30.

Based on the eigenvalue rule, where only those factors with an eigenvalue greater than 1.0 are retained (see Table 4), two factors were extracted from eight dimensions by using the PCA method. The two factors contributed 47.3% and 20.1% of the total variance respectively (cumulative 67.5%). Specifically, the environmental factor was found to exhibit the highest variance followed by the economic factor. In addition, this solution was supported by the Scree test technique (see Fig. 4). It displays factors above the inflection point (elbow).

Varimax rotation is used for this factor analysis. Since it optimises the factor structure, the relative importance of the significant factors is equalised. Hair et al. (2010) stated that factor naming will be influenced by variables with a higher loading. In addition, the selection of factor names should be related to the basic objective of the factor analysis. Therefore, the factors were labelled based on the dimensions that were highly loaded on them and on the basic purpose of the analysis. The EFA of the eight dimensions under "sustainability awareness" revealed two factors (see Table 5). Significant dimensions loading on each component enable the researcher to assign an accurate name that reflects the variables loaded on that factor. Variables loaded on the first factor are strongly related to the environmental factor of using AR in education. This was labelled "environmental factor".

The first dimension focused on was the awareness of carbon footprint reduction when using AR in education. Following this, the second dimension reflected how the use of AR can help to reduce global climate warming. The third dimension concerned air pollution. The second factor clustered four dimensions related to the reduction of consumption, waste of raw materials, and direct

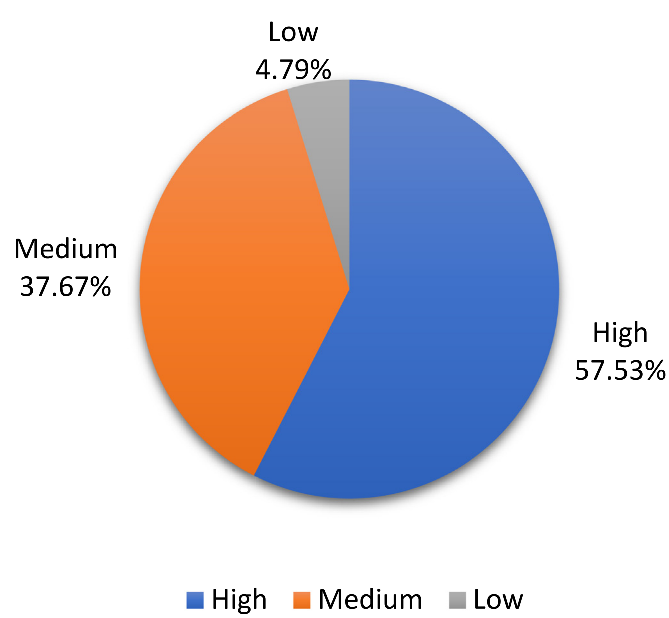

Fig. 3. Academics' educational usage of technology.

Table 2
Descriptive statistics of the sustainability awareness of AR use in higher education.

Statement	Mean[a]	Median	Std. Deviation
1. AR can reduce energy	3.32	3.00	1.009
2. AR can reduce raw materials (printed books, etc.)	4.03	4.00	.862
3. AR can reduce ICT equipment used in learning such as PCs, devices and labs	3.54	4.00	1.067
4. AR can reduce teachers' face-to-face lecture time	3.62	4.00	1.061
5. AR can reduce consumption and waste of resources	3.70	4.00	.984
6. AR can reduce air pollution	3.39	3.50	1.016
7. AR can reduce global climate warming	3.27	3.00	.987
8. AR can reduce carbon footprint	3.36	3.00	.986
Average	3.5	3.6	1.0

[a] The scale was: 1 = SD, 2 = D, 3 = N, 4 = A, 5 = SA.

Table 3
KMO and Bartlett's test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		.813
Bartlett's Test of Sphericity	Approx. Chi-Square	922.767
	df	28
	Sig.	.000

Table 4
Total variance explained.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.791	47.384	47.384	3.791	47.384	47.384	3.017	37.716	37.716
2	1.613	20.166	67.550	1.613	20.166	67.550	2.387	29.834	67.550
3	.741	9.262	76.812						
4	.600	7.499	84.311						
5	.487	6.093	90.405						
6	.413	5.160	95.565						
7	.222	2.781	98.346						
8	.132	1.654	100.000						

human communication in an AR learning environment. It was labelled "economic factor". The first dimension focused on how the use of AR will help to reduce the amount of ICT equipment needed for teaching and learning purposes. The second variable related to reducing raw materials such as those used for printing books. The third variable focused on saving energy. The fourth variable reflected the awareness of AR technology use in saving time and effort for teachers by reducing teachers' face-to-face lecture time.

Based on Hair et al. (2010) factorability determination roles,

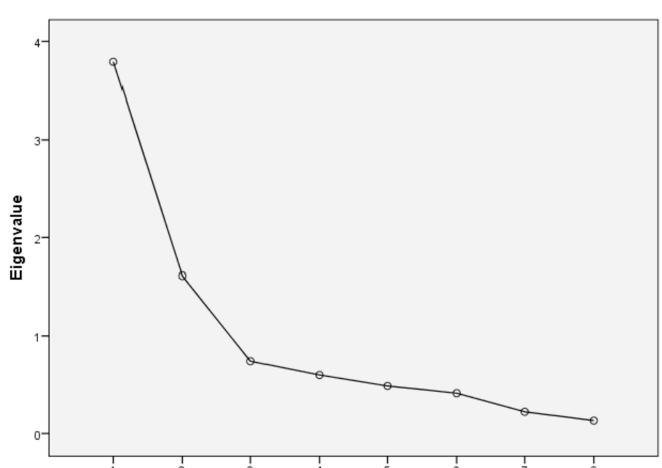

Fig. 4. Scree plot.

dimensions with a cross loading of 0.3 or above were removed and are highlighted in red in Table 5. When loadings were less than 0.35, they were excluded to enable easier interpretation. Factor loadings, communalities, and Cronbach's α are summarised below.

Accordingly, the number of initial dimensions was reduced to seven. The minimum highest value was a 0.490 factor loading for both components, which is considered as a fair loading by Tabachnick and Fidell (2007). Both factors (environmental and economic) have acceptable values of alpha coefficients of 0.926 and 0.730 respectively, thereby confirming the internal consistency reliability of the factor dimensions.

5.3. *Internal consistency reliability*

Internal consistency reliability was defined by Fink (2003, p. 3) as "refer [ring] to the extent to which all the items or questions assess the same skill, characteristic, or quality". Internal consistency reliability refers to a technique that is utilised to ensure that a survey or test succeeds in evaluating what is wanted. Cronbach's alpha is considered as one of the most common reliability statistical tests and is widely used to test internal consistency reliability. Cronbach's alpha coefficient test was developed by Cronbach (1951) to measure the reliability of the average correlation of dimensions or scales in a survey instrument. The alpha coefficient values range from 0 (inconsistent) to 1 (good consistent). The higher the value, the more reliable is the established scale. Based on Hair et al. (2010), the acceptable value threshold for an alpha coefficient is 0.70. The internal consistency for the survey in this study, using the alpha coefficient, was 0.797, which is almost

Table 5
Rotated component matrix and communalities.

Factor Label	Full set of 8 variables	Factors		Communalities
		1	2	
Environmental Factor	AR can reduce carbon footprint	.920		.863
	AR can reduce global climate warming	.914		.851
	AR can reduce air Pollution	.911		.844
	AR can reduce consumption and waste of resources	.645	.457	.625
Economic Factor	AR can reduce ICT equipment used in learning such as PCs, devices and labs		.766	.599
	AR can reduce raw material (printed books etc.)		.764	.619
	AR can reduce energy		.698	.490
	AR can reduce a direct teacher's face-to-face lecture time		.688	.513
	Number of test measures	**3**	**4**	
	Alpha Reliability α	926	.730	

consistent. Tables 6 and 7 illustrate factors and the reliability statistics of the survey dimensions.

6. Discussion

It is evident from the literature reviewed for the purpose of this research that in higher education, in particular, many institutions and universities have integrated environmental initiatives and adopted more sustainable educational approaches (Aktas et al., 2015; Anand et al., 2015; Lozano et al., 2015). Several studies have been conducted to examine sustainability awareness and perception in higher education in developing countries (Abd-Razak et al., 2011; Albahlal et al., 2017; Yuan and Zuo, 2013), but have omitted exploring awareness of new technologies that facilitate sustainable development. This study was conducted with the aim of identifying the extent to which participants were aware of the advantages of using AR to promote sustainability in Saudi higher education institutions. As mentioned in the literature review, innovative educational approaches and technologies in HE promotes sustainable development with environmental preservation and the possibility of sustainable economic (Mota and Oliveira, 2014). According to Raisinghani and Idemudia (2019), the implementation of technology has brought a drastic transformation in the societal behaviors, which imposes significant impacts on the underlying environment. This innovation had further led to the introduction of green information system, thereby resulting into advancing eco-sustainability and reducing environmental threats. It also helped in curtailing the costs associated with the IT practices, which further contributed into maintaining economic sustainability in the long run (Raisinghani and Idemudia, 2019). This study result show that, two factors of sustainable AR (environmental factor and economic factor) have been identified using EFA sample data sets ($n = 228$) of teachers (academics) and e-learning department staff from universities in Saudi Arabia. Based on the results, teachers (academics) and e-learning department staff are aware that the implementation of AR in higher education can lead to several benefits in terms of encouraging sustainability in Saudi Arabian universities and aligning with the three pillars of the TBL. This finding corroborates the ideas of Daniela et al. (2018) who suggested that "at a time when HE institutions are looking for technological solutions that support students in the learning process but are at the same time looking for possibilities to reduce expenditures, it is important to bear in mind all aspects which can influence the sustainability of education during the process of transformation" (p. 18). New factors were derived from the research findings, as seen in Fig. 5. Fig. 5 demonstrates factors related to the awareness that sustainability can be achieved by AR, based on data obtained from Saudi Arabian universities.

Table 6
Reliability statistics for all dimensions.

Cronbach's Alpha	N of dimensions
.797	7

Table 7
Reliability statistics for each factor.

Factor labels	Alpha Reliability
Environmental Factor	.926
Economic Factor	.730

6.1. Environmental factor

Factor one is related to environment benefits, which account for several dimensions ($n = 3$) including concepts such as carbon footprint, global climate warming, and air pollution (see Table 5). The results of this study are explained by the facts regarding environment benefits as faculty academic staff are aware of AR technology use in the education domain. Using AR in higher education will reduce the need for manufactured resources which in turn leads to less carbon emissions and therefore less exposure to air pollution as it is already indicated in the research carried out by (Campbell and Campbell, 2011; Harizan et al., 2015) who found important environmental impacts of adopting innovative educational approaches in HEIs. CO_2 emissions of 5–10 tons per semester were reduced via offering a course online and, students ' satisfaction with distance learning could be improved by knowing such an environmental benefit (Campbell and Campbell, 2011). Dawe, Jucker, and Martin (2005) mentioned that the survey conducted in this study contributed largely to identify the connections of the curriculum with respect to the agenda of sustainability. Besides, a wider range of disciplines has also been introduced pertaining to the themes namely biodiversity, climate change and environmental management systems. Still, it has not been able to reflect a clear viewpoint due to the presence of certain gaps in the fields of eco-efficiency, sustainable production and consumption as well as national and international sustainable development policy. However, as reflected in the report of IISD (2001), economic growth has immense contribution in maintaining organisational sustainability as compared to the environmental issues that are somewhat substantial in nature. It is therefore immensely important for the authorised bodies to initiate stricter regulations associated with the environmental factor for ensuring sustainable development of the organisations and their individual growth in this competitive financial world. This may hence result in maintaining a positive trade-off relationship between healthy growth as well as vigorous environment, constraining the business opportunities to a large

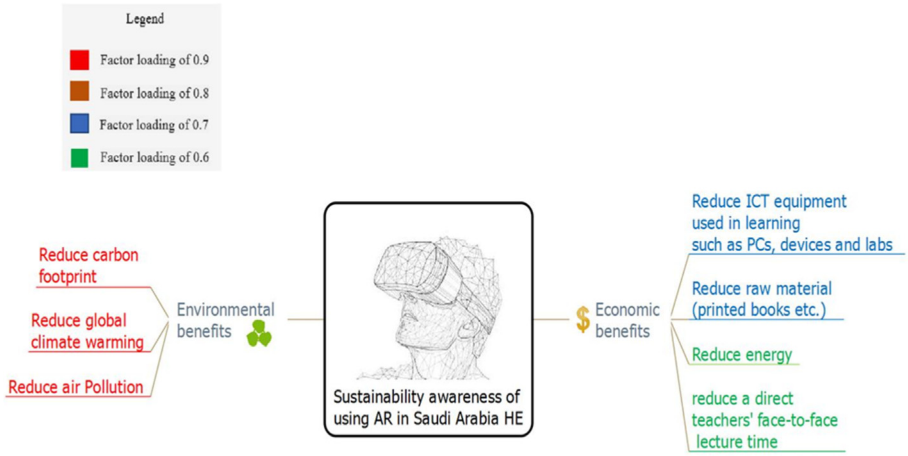

Fig. 5. Factors related to sustainability awareness of using AR in Saudi Arabian HE.

extent (IISD, 2001).

However, this study aims to examine the faculty readiness and awareness of the economic and environmental benefits of augmented reality, based on these findings, maybe they will encourage to use AR in their work in the future. The study result confirmed the study aims, by examining faculty members' awareness; it will also assist faculty members to raise sustainability awareness among their students, especially the relationship between smart technology (including AR) and sustainability. Faculty members in SA universities acknowledged that implementing AR technology in HE is associated with a variety of environmental benefits such reduce carbon footprint, global climate warming, and air pollution. Finally, universities, especially in Saudi Arabia, should take this lead by changing their faculty members and students' mindsets and their moral responsibility to contribute to sustainable development and guide them to a better, more sustainable future (Issa et al., 2017).

6.2. Economic factor

Factor two concerns the economic dimensions. It includes concepts such as raw materials, energy, and teacher performance. Respondents believed that using AR in education could decrease the amount of ICT equipment needed for learning and teaching in HE and gave this dimension a rating of 0.766. This leads to the potential for reducing the consumption of raw materials needed for printing books (0.764), thereby reducing costs. A positive correlation between AR and cost reduction has been reported in the literature (Bacca et al., 2014; Carbonell Carrera and Bermejo Asensio, 2017; Ferrer-Torregrosa et al., 2015). These results are consistent with those of other studies and suggest that AR can reduce lecturers' direct face-to-face lecture time, which allows them to have sustainable performance and more energy over more hours of lecture times (Ayer et al., 2016; Martin-Gutierrez et al., 2012). Daniela, Visvizi, Gutiérrez-Braojos, and Lytras (2018) & Ferris (2011) stated that technology can be considered as an educational tool, which further serves as an online material for conducting the process of digitized learning successfully. The learners at certain instances are even accompanied by technology for gathering knowledge on varied study fields. It helps in improving the skills-acquisition outcomes by duly considering the contexts of civic engagement and critical thinking, thereby strengthening the mental state of the individuals to grab the upcoming opportunities (Daniela et al., 2018; Ferris, 2011). Contextually, it can be inferred from the findings of Harmon and Auseklis (2009), Motochi et al. (2017) as well as Pazowski (2015) that the green practices of computing in the forms of virtualization, recycling, power management, infrastructural optimization, improvised cooling technology, and electronic waste disposal among others need to be integrated. This is due to the reason to enable the organisations in attaining sustainable development of the IT services in the long run. It has been apparent that 50% of the complete consumption of energy by a business unit constitutes its IT department's power utilization. The costs associated with this power consumption can be curtailed at least to some extent with the support of the green technology, resulting into higher level of societal and customer value in the future (Harmon and Auseklis, 2009).

In this context, it has been identified by Mago (2017) and Dastbaz et al. (2015) that the top management support, government support, green it attitude, green it policies, green it practices, green IT technology must be properly aligned in the form of a metric with the business proceedings for the attainment of both economic and environmental sustainability in the future (Mago, 2017; Dastbaz et al., 2015). Since Saudi Arabia's Vision 2030 aims to develop an education system that contributes to economic growth, the adoption of technological innovations such as AR that contribute to sustainable development has become much more important to Saudi Arabia's higher education sector. The main contribution of this study is its indication that the use of AR in the Saudi education system is expected to improve the teaching and learning experience and will encourage faculty members to develop further novel teaching strategies that engage students in their learning and encourage deep thinking in various practical and theoretical fields. It also enables decision makers to better understand the consequences of certain education and learning AR strategies implemented within their institutions, and how the impacts of the AR strategies reflect on the sustainability of the education system delivered at a national level. Finally, Issa et al. (2017) indicate that to be sustainable, exercise good stewardship and act sensibly, individuals and organisations must integrate sustainability strategies in their activities. This can be done via various resources and technologies such as green IT and smart technology in order to conserve resources, energy and raw materials while serving crucial social needs.

7. Conclusion, limitations and future work

This study has its limitations. AR is still a new technology and some of the participants were not familiar with it, so it was difficult for the researcher to find data from an exploratory source. As a result, one method that could be explored in future is the use of neural networks in order to enhance the predictions made regarding the analysed data. The current study was limited to assessing the sustainability awareness of participants in terms of the economy and environment and sought the opinions only of academics and e-learning staff in the SA higher education sector. This study was limited to examining two aspects (economic and environmental sustainability benefits), while in future other aspects (the social, cultural and political issues) should be explored. Future work could investigate and compare countries that are similar to Saudi Arabia in terms of size and gross domestic product (GDP), in order to provide a better regional perspective. In addition, more factors that assess each of the sustainability pillars examined in this research can be added to cover a broader sustainability perspective. It is anticipated that the findings from this study will provide insights which may guide further studies on the use of AR in the Gulf Cooperation Council countries. Future studies could also extend this research to include more comprehensive observations and practical applications of an AR system in a real-life setting. The current researchers are working on a generic framework for assessing growth in the use of AR technology in Saudi universities as a means of enhancing existing learning systems.

This study was intended to determine the awareness of academic and e-learning staff regarding the economic and environmental benefits of AR for sustainability in Saudi Arabian universities. The quantitative results of this research study showed that, in general, while one aim is to enhance the efficiency and sustainability of higher education in Saudi Arabia and to achieve the goals of the Saudi Vision 2030, adopting innovative educational approaches such as AR in the learning and teaching process will benefit sustainability in Saudi higher education.

The online survey conducted with Saudi academic participants examined the potential economic and environmental impacts of AR use in higher education. Two factors of the eight dimensions under "sustainability awareness" were retrieved, namely environmental and economic factors. The study confirms that the use of AR in higher education in SA will make SA academic staff and students aware of sustainability, which aligns with the Saudi Arabia Vision 2030 that aims to have at least five Saudi universities competing with the world's top universities in international rankings through the integration of innovative teaching and learning strategies that incorporate examples and principles of sustainability. It also will contribute to a better understanding of the adoption of modern educational technologies that affect higher education and provide evidence of how innovation can support sustainability. Until recently, to the best of the researchers' knowledge, no research has been conducted on awareness of sustainability related to the use of AR by academic staff in Saudi universities. This study identified the extent of this awareness by means of an online survey. In the future further research will be carried out to examine sustainability awareness of AR use in SA higher education through experiential data from academic and e-learning staff perspectives.

8. Declarations of interest

None.

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