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ORIGINAL ARTICLE

Examining Student Perception on Mobile Augmented Reality Integration, Gender Differences, Learning Styles, Feedback, Challenges, and Opportunities in an Online Physics Class

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ABSTRACT

This study aimed to investigate the perception of STEM students (n = 147) on using mobile Augmented Reality (AR) across gender and learning styles in physics online classes. It utilized embedded mixed-method research and purposive sampling. An instrument named Students Perception in Integrating Mobile AR in Physics Class was developed and has undergone a series of validations such as item generation from literature review, content validation, cognitive interview, pilot testing, and exploratory factor analysis revealing two factors, CFA with indices that are of acceptable value, and good Cronbach alpha ($\alpha = 0.86$) for reliability. Mean, standard deviation, percentages, two samples t-test, and thematic analysis were used to analyze the data. Results revealed that all students have a source of internet connection as well as a device to use and most of them have a very stable to somewhat stable internet connection. Positive feedback was shown in terms of overall learning experience and perception across gender and learning styles. However, in terms of overall usability, females have more ease of use compared to males and kinesthetic learners only have a positive response. It was also found that there is no significant difference across gender. Moreover, the integration of AR in a physics lesson has received excellent responses from both students with and without prior experience in a classroom setting. All of the difficulties the students encountered were technological in nature. There are also opportunities to improve the integration of mobile AR in the technical and learning process. These results suggest that teachers should integrate mobile AR in online physics classes but should consider factors such as Internet connection, device, gender, and learning styles in developing the application.

KEY WORDS: Augmented reality; gender difference; learning styles; online physics class

INTRODUCTION

In an online learning setup, teachers and students communicate using electronic technology and media to deliver, support, and enhance both learning and teaching (Howlett et al., 2009). Given that educational technology is a vital part of online learning, it is essential that its potential be further explored. One of the approaches in educational technology that is gaining interest is the use of augmented reality (AR) technology. AR technology enables users to see the real world with digital information superimposed (Azuma, 1997). The most accessible and preferred kind of AR technology is through the use of a mobile device or what is called mobile AR (Sirakaya and Sirakaya, 2018). Various studies revealed that the use of mobile AR technology could improve students' motivation, confidence, and satisfaction (Cai et al., 2014). The use of mobile AR in Philippine education is continuously rising, one of which is the use of textbook-based AR. Recent studies have found that the use of AR technology as a learning tool in the field of Physics education has been effective (Abdusselam and Karal, 2020; Cai et al., 2021). Moreover, it was also proven effective even during the COVID-19 pandemic as it was used as an alternative learning tool during online physics class (Ropawandi et al., 2022). The impact of the pandemic raised the need to ensure quality education post-pandemic, especially in the local setting (Pelayo-Dacanay et al., 2023). With this, the study explored the perception of the students regarding the integration of AR into an online physics class.

LITERATURE REVIEW

AR

AR is part of the virtuality continuum shown in Figure 1 which is a scale created by Milgram and Kishino (1994) between a real environment with no enhancement, towards a virtual environment enhanced fully by a computer. A study conducted by Sumadio and Rambli (2010) revealed that AR applications in education are well accepted with very positive feedback even from participants with no previous experience using it.

The definition of AR comprises three things: the combination of the virtual world and the real world, interaction in real-time, and 3D registration (Hantono et al., 2018). Given its technological capability, Phon et al. (2014) described it to have a promising instructional importance and open new approaches to education.

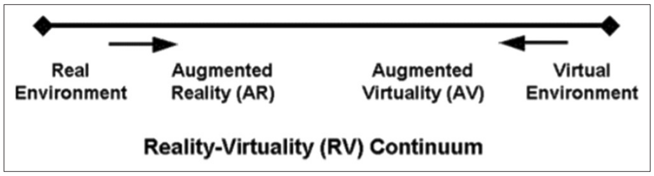

Figure 1: Virtuality Continuum (by Milgram and Kishino, 1994)

AR in Education and Gender Difference

Studies concerning the gender difference in using AR in general and even specifically in education are barely sufficient according to Dirin et al. (2019). Given the said status of research in AR in education across gender, the researcher also included studies on gender differences in using mobile technology in general since it also shares the same concept with AR mobile technology. It was found that males adopt easily compared to females in using mobile technology, perform better and that the perceived use of males is higher compared to females (Ahmad et al., 2005; Hamza and Shah, 2014; Kongaut and Bohlin, 2016; Hsu, 2017) although no significant difference was found across gender. Interestingly, Dünser et al. (2006) and Echeverría et al. (2012) found a significant difference between males and females in terms of using AR and non-AR technology, and males performed better than females. On the other hand, there are also studies concluding that females benefited more than males in using AR. One of these is the study of Dirin et al. (2019). They conducted a study where students did experiments on virtual reality, AR, and conventional video to assess personal factors including gender differences in perceiving and adopting the said technologies. The result revealed that females are more enthusiastic about using AR. The same result was revealed by the study of Kimbrough et al. (2013) which indicates that females are more interested in interaction with AR than males. Moreover, Pantano et al. (2017) found that both males and females are equal in terms of perception of ease of use of AR but the satisfaction of males was higher than females.

These studies found mixed results in terms of the gender difference in the perception and use of AR technology in a traditional learning setting. A similar study applied to online learning settings is still not well established. With this, it is essential to be examined to determine if gender difference in the perception and use of AR also applies to online learning settings. This is noteworthy since the current mode of access to education is online.

AR in Education and Learning Styles

Learning styles are the preferences of students in learning which can help teachers effectively address the needs of the students. In addition, different models of learning styles were developed over the past 5 decades (Chen and Wang, 2017). One of these learning style models is by Fleming and Mills (1992) called the VARK (Visual, Auditory, Reading and Writing, and Kinesthetic) model which will be used by this study in identifying the learning styles of the students. According to Chen and Wang (2017), there is a mixed results regarding the effect of individual differences on learning outcomes with technology-assisted instruction.

Research about the perceptions of students in integrating AR in a class according to learning style is also scant. Zhang et al. (2016) conducted an 8-week-long AR-assisted learning activity for elementary school students to determine its influence on learners of different learning styles. Their findings suggest that AR can be beneficial to kinesthetic learners, and possibly for visual learners as well. Furthermore, they also found out that AR has less effect on the attention of auditory learners in elementary science instructions.

Medina et al. (2017) explored the learning styles according to the VARK model of higher education students as a basis for planning, assigning, and use of digital learning objects (DLO) with AR. It was found that students who experienced the treatment had better performance compared to those who did not.

These researchers prove that designing a technology-assisted instructional material would have a better result if aligned to the learning styles of the students, but since limited studies are focused on this, further verification is needed especially in a local online context.

The researcher took these earlier studies into account and used them as a springboard for the current study.

Statement of the Problem

In this framework, answers will be sought to the following questions in the context of the General Physics online class:

1. What is the status of online learning accessibility of the respondents?
2. What is the perception of the students in integrating mobile AR in physics class according to:
   a. Gender
   b. Learning style
3. Is there a significant difference in students' perception between male and female students?
4. What is the overall feedback of the students on integrating mobile AR in physics class based on experience?
5. What are the challenges and opportunities of integrating mobile AR in Physics class?

METHODOLOGY

Embedded mixed method design was used in the study and purposive sampling was employed in determining the research participants which were the Grade 12 STEM students (n = 147) comprising 72 males and 75 females.

The tool that was used in gathering the data was the researcher-developed instrument which was the Students' Perception in Integrating Mobile AR in Physics. The researcher developed the 16-item Likert-type scale instrument with 1 as strongly disagree and 5 as strongly agree. It is divided into two subscales, the usability and learning experience. The usability subscale on the survey portrays negative statements, meaning the higher the mean of this, the higher the disagreement of the students to these negative statements (5 pertains to strongly disagree and 1 pertains to strongly agree).

Data Collection Procedure

The lack of an instrument for measuring students' perceived advantages and challenges in integrating mobile AR in physics class made the researcher develop and validate an instrument called Students Perception in Integrating Mobile AR in Physics Class (SPIMAR-PC).

Literature review and item generation

The first step in developing the instrument was reviewing related literature that will measure the perception of students in integrating mobile AR in physics class. The review of related literature focused on the advantages of using AR and then specified it as mobile AR since that is the specific kind of AR that is planned to be integrated into physics class.

There are numerous literature that discusses the advantages of using AR in different scenarios. The most commonly cited advantages in the literature are the improvement in the following: spatial skills, instruction, achievement, performance, motivation, attitude, engagement, interaction (student–student, student–teacher), learning gain, and satisfaction. Furthermore, enabling visualization and flexibility are also noted advantages, ease of use and attraction to graphics (Coffin et al., 2010; Cerqueira and Kirner, 2012; Singhal et al., 2012; Akçayır and Akçayır, 2016; Garzon et al., 2019; Altinpulluk, 2019). With all these identified advantages, the researcher divided these into two categories which are the learning experience and usability. From this, a 4-item question for the first category and initially 13 questions for the second category were generated and subjected to validation, which later on was reduced to 16.

Content validation and cognitive interviews

The initial draft of the survey was subjected to content validation by two expert physics educators. The content validation mean score was 5 using a 5-point Likert scale expert validators questionnaire. Comments of the validators are adding additional text descriptions along with the YouTube video to cater to those respondents with connectivity issues and to indicate the time it would take to finish the survey.

Cognitive interviews were also done. The participants were asked several probing questions which led to the identification of the statement "I experience low sensitivity in trigger recognition" to be the only difficult statement for the students to understand. This was considered and resulted in the modification of the said statement to "I experience difficulty making mobile AR appear".

Pilot testing

The instrument was administered to grade 12 STEM students (n = 137) in the same university but in different classes. They were asked to download a sample mobile AR application namely AR Physics which has an activity for Newton's first law of motion to ensure that they will have an idea of how mobile AR works aside from the YouTube video and text description.

Construct validity

Exploratory factor analysis (EFA)

The data gathered from the respondents (n = 137) were subjected to EFA. The minimum sample size needed to conduct the said statistical analysis varies in different literature (Williams et al., 2010). One of these is the suggestion of Hair et al. (1995) that the sample size should be 100 or greater which was met by this study. Initially, all 17 items were examined according to their factorability through the examination of a set of criteria. The correlation matrix revealed that all items except item no. 16 correlated at equal or >0.3 with at least one item. Hair et al. (1995) categorized correlation loading ≥±0.30 to have met the minimal level to accept an item to belong in a factor. This was also supported by Tabachnick and Fidell (2007) which states that the said value is already sufficient. For the Kaiser–Meyer–Olkin measure of sampling adequacy, a value of.889 was retrieved which was higher than the standard value of 0.6 while Bartlett's test of sphericity was significant ($\chi2$ (136) = 1333.071, $p < 0.05$). Finally, the communalities were all above 0.3 for all items except item no. 16. Given that all criteria were met, it was concluded that factor analysis was applicable for the said instrument. Table 1 shows the initial result of the factor loading of the instrument. It can be observed that item no. 16 did not produced any factor loading

Table 1: Initial exploratory factor analysis of the items of the SPIMAR-PC questionnaire notes

Items	Factor		
	1	2	3
1. I understand the concept easily using mobile AR Technology	**0.826**		
2. I believe I can perform better in Physics with the use of mobile AR Technology	**0.804**		
3. I believe mobile AR Technology can help improve spatial skills	**0.783**		
4. I am interested in doing the activity using mobile AR Technology	**0.778**		
5. Doing activities with mobile AR Technology enhance my satisfaction	**0.771**		
6. Using mobile AR Technology improves my motivation to learn	**0.762**		
7. Mobile AR Technology provides continuous engagement	**0.751**		
8. Mobile AR Technology created a sense of reality	**0.634**		
9. I can manage to do activity with mobile AR Technology independently	**0.583**		
10. I learn physics better with visual/multimedia materials (picture, videos, 3d model)	**0.576**		
11. I like the graphics and images in this activity	**0.530**		
12. I find it difficult to use AR Technology		**0.761**	
13. I believe I do not have the technical skills to use AR Technology		**0.725**	
14. I find the use of mobile AR Technology boring		**0.659**	
15. I experience low sensitivity in trigger recognition		**0.553**	
16. I like learning physics through the teacher's discussion than exploring it using mobile AR Technology			
17. Mobile AR Technology is flexible (can be used for face-to-face or online class)	0.501		0.535

Extraction method: Principal Axis Factoring; Rotation method: Varimax with Kaiser Normalization. The largest loadings are in bold value. According to Hooper (2012), these may suggest poor or unreliable items that may need to be removed from the analysis. With this, there is a need to rerun the data excluding item number 16. It should also be noted that the number of factors revealed by the total variance explained as shown in Table 2 was two. The factor extraction was examined based on eigenvalues which have >1. This revealed that factors 1–3 would qualify, but further examination using a parallel analysis revealed that two factors should only be retained making it theoretically sound.

The second run of factor analysis revealed the same result in terms of its factorability. The correlation matrix and communalities revealed that all items now have equal or >0.3 value, respectively. Moreover, the Kaiser–Meyer–Olkin measure of sampling adequacy has a value of 0.897 while Bartlett's test of sphericity was significant ($\chi 2$ (136) = 1300.705, $p < 0.05$). It verified that factor analysis can be done for the remaining items. Table 3 shows the final EFA of the remaining items and the corresponding dimension of the two identified factors.

Confirmatory factor analysis

To verify that the factor structure fits the data (Hair et al., 2015), from the results of EFA, a confirmatory factor analysis was performed using IBM SPSS AMOS version 26. Figure 2 presents the result of the confirmatory factor analysis of SPIMAR-MC. Awang (2014) suggested that for newly developed items, factor loading for every item should exceed 0.5. Results showed that all 16 items have factor loading >0.5.

To improve the model fit, covarying of errors was also done. Several statistical measurements are used to determine the fitness of a model. Kline (2015) suggested to report at a minimum the following indices: chi-square, the RMSEA, the CFI, and the SRMR. This study will also include CMIN/df, GFI, AGFI, TLI, and NFI. Table 4 which was adopted from Kumar et al. (2019) showed the ideal value and results of the said indices.

The results for the indices of CFI, CMIN/df, GFI, AGFI, and TLI were within the ideal value. The Chi-square statistics showed a significant result which was the opposite of the desired value. According to Dickey (1996), Chi-square statistics are largely affected by the sample size which is the implied reason for the said result. Although this is very useful for comparing different CFA models, it is still necessary to be reported. NFI and RMSEA values are acceptable values. With these, it can be concluded that the model fits the data.

Reliability assessment

Cronbach's alpha

To examine the internal consistency of the items in each factor, a Cronbach's alpha was performed. The overall Cronbach's' alpha was 0.86, the learning experience subscale consisted of 12 items ($\alpha = 0.93$) and the usability subscale consisted of 4 items ($\alpha = 0.76$) which have a corresponding reliability level of good, excellent, and acceptable respectively as shown in Table 5.

After the instrument was developed and validated, necessary permits were acquired and the administration of the research instrument was conducted online through a Google form. Data were retrieved afterward into an Excel file for analysis.

Data Analysis

The analysis and interpretation of quantitative data were done using several statistical tools and with the help of statistical software SPSS version 20. Mean, percentage, and standard deviation were used for the descriptive statistics while two sample t-tests were for the inferential statistics. For the analysis and interpretation of the qualitative data, thematic analysis was used by Braun and Clarke (2006).

FINDINGS AND DISCUSSIONS

Status of Online Learning Accessibility of the Respondents

Figure 3 shows the identified internet accessibility of the respondent. All four identified sources of internet connection reveal a greater number of very stable, stable, and somewhat stable connections in combination compared to not stable connections. This agrees with the result found by Baticulon et al. (2021) that most of the students doing online classes have a source of internet connection but are having trouble continuously using it.

Figure 4 shows the available learning devices of the respondents. It revealed that most of the students have both laptops/desktops and smartphones as an available learning device. These results only imply that integrating mobile AR in physics class is feasible, internet connection, and equipment-wise. However, it should be expected that connection and device problems could occur given the said data which reflects on their responses. Since it is very much possible to happen, a plan should be ready in case the said circumstance happens so that the intervention would be smooth and ensure that the students would still attain the lesson's objectives.

Table 2: Initial total variance explained by the first four factors

Factor	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	6.973	41.016	41.016	6.572	38.657	38.657	5.927	34.865	34.865
2	2.529	14.879	55.895	2.022	11.892	50.549	2.048	12.048	46.913
3	1.017	5.983	61.878	0.542	3.189	53.738	1.160	6.826	53.738
4	0.902	5.308	67.186						

Table 3: *Initial* exploratory factor analysis of the items of the *SPIMAR-PC* questionnaire

Items	Factor		Dimension
	1	2	
1. I am interested in doing the activity using mobile AR Technology	0.839		Learning experience
2. Using mobile AR Technology improves my motivation to learn	0.807		
3. I believe mobile AR Technology can help improve spatial skills	0.802		
4. I understand the concept easily using mobile AR Technology	0.793		
5. Mobile AR Technology provides continuous engagement	0.780		
6. I believe I can perform better in Physics with the use of mobile AR Technology	0.764		
7. Doing activities with mobile AR Technology enhance my satisfaction	0.762		
8. Mobile AR Technology created a sense of reality	0.734		
9. I like the graphics and images in this activity	0.662		
10. Mobile AR Technology is flexible (can be used for face to face or online class)	0.631		
11. I can manage to do activity with mobile AR Technology independently	0.597		
12. I learn physics better with visual/multimedia materials (picture, videos, 3d model)	0.575		
13. I find it difficult to use AR Technology		0.740	Usability
14. I believe I do not have the technical skills to use AR Technology		0.734	
15. I find the use of mobile AR Technology boring		0.638	
16. I experience low sensitivity in trigger recognition		0.566	

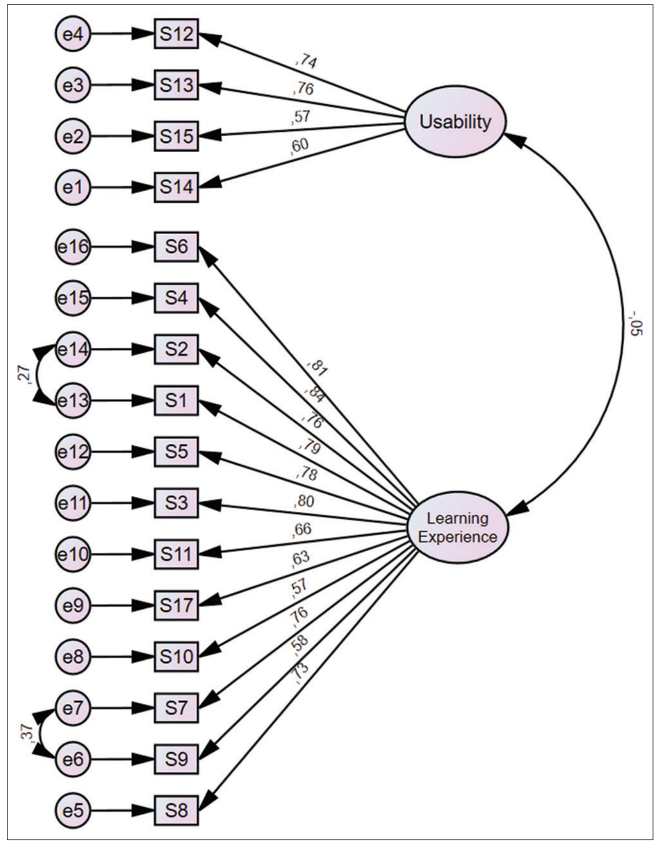

Figure 2: Result of the confirmatory factor analysis of the SPIMAR-PC

Perception of the Students in Integrating Mobile AR in Physics Class

Students' perceptions of integrating mobile AR in physics class in an online class context were compared through mean and standard deviation across gender in Table 6 and learning style in Table 7. Each of the mean was given its verbal interpretation as presented in Table 8 based on the range presented by Pimentel (2010) in his study.

Gender

Male and female respondents have positive perceptions overall and in terms of the learning experience in using mobile AR application as shown in Table 6. However, female respondents' perception of its usability has neutral feedback contrary to the positive response of the male respondents. However, since statements were negatively stated, the interpretation should be the opposite. The latter statement disagrees with the existing literature which described that male respondents adopt more easily in using mobile technology compared to females (Pantano et al., 2017). This discrepancy can be attributed to the mode of learning where the integration of AR technology happened. The online class brought by the pandemic made an impact on the motivation of male students to learn making it less than that of the female students (Atmoko et al., 2022). However, it was found that both male and female respondents have the same positive feedback contrary to the mixed literature that one has greater positive feedback compared to the other (Ahmad et al., 2005; Kimbrough et al., 2013; Hamza and Shah, 2014; Kongaut and Bohlin, 2016; Hsu, 2017; Chen et al., 2017; Dirin et al., 2019). This result should be taken note of when integrating mobile AR in a class, with this, male respondents should be monitored as they use the AR application so that it would be smoothly used. Furthermore, the data also showed that female respondents are strongly inclined to see visual aspects of the AR application as seen from the strongly agreed interpretation for item numbers 10 and 11. It only implies that the use of AR in a class would be more effective for female students if its visual aspect were improved.

Learning style

The overall learning experience and perception of all the kinds of learning styles of the students have a verbal interpretation of agree. As for the overall usability, all visual, auditory, and reading and writing learners have a neutral response while only the kinesthetic learners agree with the overall usability of the mobile AR. In the learning experience category, it can also be observed that item numbers 10 and 11 have strongly agree feedback from the visual, auditory, and kinesthetic learners. The individual items in the category of usability vary from

Table 4: Summary of measurement model of goodness of fit statistics

Indices	Ideal value	Recommended	Model indices
p-value	≥0.05	Kline (2011)	0.000
CFI	≥0.90	Carmines et al. (1981)	0.931
CMIN/df	<5	Tabachnick and Fidell (2007)	1.845
GFI	>0.80	Hair et al. (2015)	0.866
AGFI	≥0.80		0.819
TLI	>0.90	Hu and Bentler (1999)	0.918
NFI	>0.90		0.863
RMSEA	≤0.05	Byrne (1998)	0.076

Table 5: Reliability level of coefficient of Cronbach's alpha (George and Mallery, 2003)

No	Coefficient of Cronbach's Alpha	Reliability level
1	More than 0.90	Excellent
2	0.80–0.89	Good
3	0.70–0.79	Acceptable
4	0.60–0.69	Questionable
5	0.50–0.59	Poor
6	<0.59	Unacceptable

neutral to disagree except for the strongly disagree feedback of kinesthetic learners on item no. 15.

The data suggests that all types of learning styles, visual, auditory, reading and writing, and kinesthetic have a positive overall perception of the learning experience. This result agrees with the study conducted by Medina et al. (2017) where all types of learners improved their performance, an aspect of the learning experience, when given mobile AR as an intervention. In terms of overall usability, only the kinesthetic learners have a positive perception unlike the other three which have a neutral response. This was in parallel to the result of Zhang et al. (2016) where kinesthetic learners stand out in terms of receiving the benefits of using mobile AR. It only implies that the distinct aspect of kinesthetic learners who do hands-on activities was served well. However, it also reminds the developer of mobile AR applications that students of different types of learning styles should also be considered. It could also be suggested that mobile AR applications should also have other distinct learning contents preferred by other learnings such as audio/video files, lectures, or analysis.

Gender Difference in Students' Perception of Integrating Mobile AR in Physics Class

The mean scores of the overall perception of the male and female respondents in integrating mobile AR in physics class were used to conduct an independent two-sample t-test. Before conducting the said statistical tool, all three assumptions were checked. First, the independent variable must be categorical data, which was followed since the male and female variable was the independent variable. Second, the data should be normally distributed. A test of normality was conducted

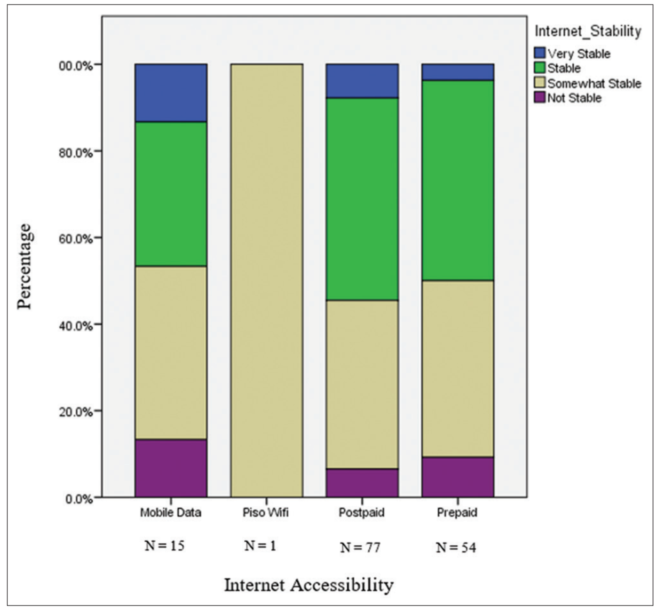

Figure 3: Internet accessibility and stability of the respondents

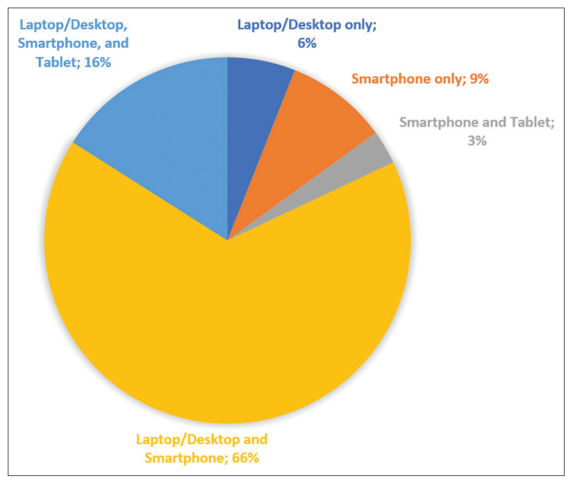

Figure 4: Available learning device of the respondents

through the Shapiro–Wilk test and showed that the data is normally distributed since the $p = 0.387$. From these two, the independent two-sample t-test was conducted. After having the result, the first thing that should be determined is whether the data have equal or unequal variances assumed through the given p-value.

Table 9 presents the result of the said statistical test and showed that $p < 0.05$. With this, the result is said to have an unequal variance assumed. There was no significant difference in the scores of male ($M = 3.42$, $SD = 0.33$) and female ($M = 3.44$, $SD = 0.45$) respondents; $t(136) = -0.343$, $p = 0.732$. This is similar to the previous research (Ahmad et al, 2005; Hamza and Shah, 2014; Kongaut and Bohlin, 2016; Hsu, 2017) though it contradicts the result of the studies of Dünser et al. (2006) and Echeverria et al. (2012) which found a significant difference. It only means that although they do differ in terms of the perception of usability, their overall perception does not

Table 6: Students' perception across gender

Statements	Male (n=72; 49%)			Female (n=75; 51%)		
	Mean	SD	Verbal Interpretation (V.I.)	Mean	SD	Verbal Interpretation (V.I.)
1. I understand the concept easily using mobile AR Technology	3.65	0.84	A	3.85	0.82	A
2. I believe I can perform better in Physics with the use of mobile AR Technology	3.49	1.06	A	3.72	0.88	A
3. I believe mobile AR Technology can help improve spatial skills	3.92	0.85	A	4.08	0.71	A
4. I am interested in doing the activity using mobile AR Technology	3.83	0.87	A	4.12	0.81	A
5. Doing activities with mobile AR Technology enhance my satisfaction	3.83	0.90	A	3.95	0.85	A
6. Using mobile AR Technology improves my motivation to learn	3.68	0.90	A	3.91	0.84	A
7. Mobile AR Technology provides continuous engagement	3.90	0.92	A	4.05	0.77	A
8. Mobile AR Technology created a sense of reality	3.96	0.83	A	4.09	0.89	A
9. I can manage to do activity with mobile AR Technology independently	3.49	1.02	A	3.83	0.89	A
10. I learn physics better with visual/multimedia materials (pictures, videos, 3d model)	4.10	1.06	A	4.20	0.93	A
11. I like the graphics and images in this activity	4.10	0.75	A	4.31	0.77	SA
12. Mobile AR Technology is flexible (can be used for face to face or online class)	3.65	0.98	A	4.04	0.95	A
13. Overall Learning Experience	3.80	0.57	A	4.01	0.74	A
14. I find it difficult to use AR Technology	2.86	1.09	N	2.71	1.06	N
15. I believe I do not have the technical skills to use AR Technology	2.43	1.12	D	2.44	0.99	D
16. I find the use of mobile AR Technology boring	2.17	1.06	D	1.96	1.07	D
17. I experience low sensitivity in trigger recognition	2.97	1.03	N	3.16	1.05	N
Overall Usability	2.61	0.51	N	2.57	0.58	D
Overall Perception	3.56	0.33	A	3.72	0.45	A

Table 7: Students' perception across learning styles

Statements	Visual (n=80; 54%)			Auditory (n=5; 3%)			Kinesthetic (n=23; 16%)			Reading and Writing (n=39; 27%)		
	Mean	SD	V.I.	Mean	SD	V.I.	Mean	SD	V.I.	Mean	SD	V.I
1. I understand the concept easily using mobile AR Technology	3.76	0.85	A	3.60	0.55	A	3.78	1.00	A	3.74	0.75	A
2. I believe I can perform better in Physics with the use of mobile AR Technology	3.65	0.96	A	3.20	0.84	N	3.74	1.01	A	3.49	0.94	A
3. I believe mobile AR Technology can help improve spatial skills	3.98	0.80	A	3.60	0.55	A	4.13	0.82	A	4.03	0.81	A
4. I am interested in doing the activity using mobile AR Technology	4.06	0.80	A	3.60	1.14	A	3.87	0.76	A	3.92	0.96	A
5. Doing activities with mobile AR Technology enhance my satisfaction	3.89	0.86	A	3.60	1.14	A	4.00	1.00	A	3.87	0.83	A
6. Using mobile AR Technology improves my motivation to learn	3.83	0.82	A	3.60	0.89	A	3.74	0.86	A	3.79	1.01	A
7. Mobile AR Technology provides continuous engagement	3.98	0.86	A	3.80	1.10	A	3.95	0.83	A	4.03	0.84	A
8. Mobile AR Technology created a sense of reality	4.06	0.83	A	3.60	0.55	A	4.00	0.80	A	4.03	0.99	A
9. I can manage to do activity with mobile AR Technology independently	3.71	0.93	A	3.40	0.89	A	3.30	1.11	N	3.79	0.95	A
10. I learn physics better with visual/multimedia materials (pictures, videos, 3d model)	4.20	1.01	A	4.00	0.71	A	4.35	1.03	SA	3.97	0.99	A
11. I like the graphics and images in this activity	4.20	0.76	A	4.40	0.55	SA	4.35	0.65	SA	4.13	0.86	A
12. Mobile AR Technology is flexible (can be used for face-to-face or online class)	3.85	0.89	A	3.40	1.51	A	3.83	1.07	A	3.92	1.06	A
13. Overall Learning Experience	3.93	0.70	A	3.65	0.44	A	3.92	0.61	A	3.89	0.67	A
14. I find it difficult to use AR Technology	2.86	1.02	N	2.80	0.44	N	2.61	1.23	N	2.67	1.16	N
15. I believe I do not have the technical skills to use AR Technology	2.51	1.11	D	2.40	0.89	D	2.30	1.11	D	2.33	0.93	D
16. I find the use of mobile AR Technology boring	2.09	1.06	D	2.20	0.45	D	1.78	1.04	SD	2.18	1.14	D
17. I experience low sensitivity in trigger recognition	3.01	1.01	N	3.20	0.84	N	2.83	1.27	N	3.31	0.98	N
Overall Usability	3.38	0.57	N	3.35	0.52	N	3.62	0.49	A	3.38	0.55	N
Overall Perception	3.66	0.36	A	3.50	0.17	A	3.77	0.41	A	3.64	0.45	A

differ from each other. This means that in terms of gender, it is positively perceived, but the usability aspect should be given much focus for female students.

Overall Feedback of the Students in Integrating Mobile AR in Physics Class Based on Experience

Table 10 summarizes the overall feedback of respondents in integrating mobile AR in physics class. Both students with and without prior experience in a classroom setting of using AR have positive feedback about integrating it into a physics class. This was consistent with what Sumadio and Rambli (2010) found out. This implies that prior experience of the student in using AR would not be a negative factor for it to be an effective instructional material. Although the mean of respondents with prior experience is greater than those who do not have experience, the difference is small which did not affect their overall feedback.

Challenges and Opportunities of Integrating Mobile AR in Physics Class

Challenges

Table 11 shows the summary of students' responses in terms of challenges experienced. It revealed that the main challenge that the students encountered was technical difficulties.

For the Internet connection speed problem and application lag, physics teachers should make the use of AR in physics class flexible so that students can do the activity again at another time when their internet connection speed is stable. In terms of device incompatibility, the application to be used in a physics class must be available for both Android and Apple users as well as those devices that are of old models. Another problem that emerged was regarding the trigger recognition. The sample application was a markerless kind of AR. Since this kind of AR needs an adequate space for it to be triggered and appear, teachers who will develop an AR instructional material should also consider that not all students have an adequate space in their home. With this, a marker-based AR can be an option to eliminate or at most lessen the said problem. Lastly, respondents also named application manipulation as the last challenge that they experienced. The researcher intentionally did not give a formal orientation and demonstration of using the sample AR. This is to determine all the possible problems that they will experience by exploring on their own. This is because even in the presence of a proper orientation, it should still be considered that not all students will be able to attend such orientation. This is similar to what previous studies (Wu et al., 2013; Dunleavy et al., 2009; Mitchell, 2011) have encountered in integrating AR in classroom settings, revealing that technological difficulty was one of the main challenges. With this, it is suggested that physics teachers should still formally orient and demonstrate to students how to use a markerless and marker-based AR. In addition, they can also prepare a written user guide so that it will be ensured that the students will be able to use the AR smoothly and effectively. However, it should be kept in mind that technological difficulty is not the only possible challenge that can be encountered in integrating AR in a classroom setting. Previous research has also found that pedagogical and learning issues (Wu et al., 2013) may arise such as the promotion of critical thinking skills (Chu et al., 2019), increase in cognitive load (Wu et al., 2018), lack of training and resistance to change of the teachers (Alkhattabi, 2017).

Opportunities

There were two identified themes from the responses of the students on how to better utilize mobile AR. The first theme was technical and under it were four categories while the second theme was learning process which has 3 categories, these were summarized in Table 12 along with the corresponding examples.

The device incompatibility problem was identified as one of the challenges experienced by the students which is why it is no wonder that they would like it to improve so that everyone will be able to use the AR in learning physics. Second is the interactive aspect of the application. Teacher developers who will use AR in teaching physics should make sure that the application is interactive so that the students will enjoy and eventually learn more. Along with these are the visual elements of the AR. It should be noted that it is not only for the benefit

Table 8: Reference table for perception interpretation

Verbal interpretation	Score interval
Strongly disagree (SD)	1.00–1.80
Disagree (D)	1.81–2.60
Neutral (N)	2.61–3.40
Agree (A)	3.41–4.20
Strongly agree (SA)	4.21–5.00

Table 9: Independent two samples t-test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	SE difference	95% Confidence interval of the difference	
								Lower	Upper
Overall									
Equal variances assumed	5.802	0.017	−0.341	145	0.733	−0.022	0.06501	−0.15067	0.10630
Equal Variances not assumed			−0.343	135.81	0.732	−0.022	0.06461	−0.14995	0.10559

Table 10: Overall feedback of respondents according to experience

Experience in using AR in any subject before	Mean	SD	Verbal interpretation
With prior experience n=84	4.04	0.88	Agree
Without prior experience n=63	3.97	0.97	Agree

Table 11: Thematic analysis for the challenges experienced

Theme	Categories	Examples
Technical difficulties	Internet connection speed	*"…Second is that the internet is sometimes slow sometimes fast."*
		"None, aside from signal issues on the Internet"
	Application Lag	*"I suppose that would be the lagging…"*
		"I encounter some difficulties like delay and lag on the app while using it"
	Device Incompatibility	*"…I think that some low-end devices may not be able to support Augmented/Virtual Reality."*
		"Not compatible on some devices"
	Trigger Recognition	*"…it's hard to scan some object"*
		"First, the scanning part wherein my device can't scan certain parts of the floor…"
	Application Manipulation	*"The subtitles are too close on the screen, so you really need to adjust your phone."*
		"…some of the lessons provided on the screen cannot be read properly."

Table 12: Thematic analysis of the opportunities for improvement

Category	Examples
Technical	
Device compatibility	*"…access to other mobiles such as people who use iPhone who can't access this app…"*
	"…AR technology apps were accessible on all devices, such as IOS, Android, or computers."
Interactive	*"It needs to be more interactive to allow learners to focus more on practice instead of just laws."*
	"Add more features that have interaction."
Visual elements	*"…add more digital animation so the students or even teacher will enjoy the AR technology…"*
	"…try to make the graphics more amusing and more realistic."
Trigger recognition	*"Maybe the app AR Physics can further improve its floor recognition…"*
	"Enhance the sensitivity and improve the technology in its sensor."
Learning process	
Integration in subject	*"Apply AR technology in class so the student can have an experience to test their knowledge in practice."*
	"Normalize using AR Tech when teaching physics lessons."
Content	*"More concepts about physics…"*
	"It should cover a lot of concepts about Physics."
Orientation and demonstration	*"Teach and explain to students on the basic things on how to use it."*
	"Mobile AR Tech should be more flexible and easier for us students who are willing to learn and use this kind of technology."

of visual learners but of all types of learning styles. Ensuring this would make the integration of AR more effective. The second theme was the learning process. Students would like AR to be integrated into their subjects not just in physics. It should be considered by the other subject area given its benefits and the current mode of learning. In terms of the content, the respondents would like the use of AR to incorporate more concepts or if possible, all the most essential learning competencies. So that its full benefits will be experienced by both the teachers and students for the entire subject. And finally, respondents would like to be properly oriented and shown a formal demonstration of how to use AR. This implies that teachers who will use AR as an intervention or instructional material should always make the orientation and demonstration a vital part of the process.

CONCLUSION

Most of the students were found to have mobile or laptop devices to use and have good source of Internet access with a small portion having unstable connections. The overall perception and learning experience in using mobile AR across gender and learning styles both have a positive result. However, it revealed that for overall usability females tend to have more ease than males and only kinesthetic learners have a positive response to the learning style. Furthermore, no significant difference was found between male and female students. Both students with and without prior experience in a classroom setting of using AR have positive feedback about integrating it into a physics class. Challenges encountered by the students are all in the technical aspects. Moreover, opportunities for improving the integration of mobile AR are in the technical and learning process.

Recommendations

Based on the established conclusions, the following recommendations are suggested:

1. Examine further the discrepancy in gender difference in terms of the perceived usability of integrating mobile AR in a classroom setting.
2. Investigate advancements in mobile AR technology, focusing on improving rendering capabilities, device compatibility, and network connectivity.
3. Explore innovative approaches to integrating mobile AR into the learning process, such as developing AR-enhanced curriculum materials and learning activities.

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