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# A Pilot Program to Introduce Augmented Reality to Female Hispanic High School Students in STEM Education

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## Abstract

Augmented Reality (AR) allows users wearing special glasses (such as Microsoft HoloLens 2, Apple Vision Pro, Trimble XR-10, Oculus Quest 2, Vuzix Blade, etc.) to see and interact with information generated by a computer overlaid on the real world. AR's interactive, immersive, and engaging features could transform learning experiences, particularly for female students drawn by these features. The problem motivating this paper is that females make up only 34% of the workforce in Science, Technology, Engineering, and Math (STEM). Therefore, as part of this research, Augmented Reality was introduced to female Hispanic high school students with the objective of 1- Identifying students' familiarity with AR, 2- Identifying students' initial impression, 3- Capturing the challenges encountered while using AR, 4- Capturing participants' interest for AR use for an extended period, and 5- Assessing potentials of AR to enhance learning and education among female students. A pre-experimental research design, more specifically, a one-shot case study, was used to introduce STEM using AR (Trimble XR-10 with HoloLens 2) to a group of female Hispanic high school students from rural high schools during a summer camp. After the STEM activity using the AR, the participants completed an online survey with mainly closed-ended questions. The research results are encouraging as all female Hispanic high school students who participated in the activity believed that AR has the potential to enhance their STEM learning and education experiences. The two features that stood out the most were visual quality and interactivity. All participants indicated that AR enhanced their understanding of the topic. The results of this research are vital as there is a growing trend towards the use of AR in STEM fields and STEM education, but limited knowledge exists about the challenges encountered by females when experiencing the AR environment especially when females perceive AR differently than males. The preliminary findings highlight the need for improvements in comfort and user interfaces. AR has the potential to transform education with further research and refinement, which are essential for successful integration into learning environments.

**Keywords:** STEM, Education, Augmented Reality (AR), Female, Hispanic, High School students

## Introduction

The absence of females in STEM occupations is nothing new, it was brought into sharp focus by Shirley Malcolm, Paula Hall, and Janet Brown in 1976 with their groundbreaking book, "The Double Bind: The Price of Being a Minority Women in Science" [1]. This work highlighted the challenges faced by minority females in STEM. Despite the advancements in awareness and efforts to promote diversity, the underrepresentation of females, particularly females Hispanic, in STEM fields remains a challenge today [2]. In fact, females make up only 34% of the workforce in STEM [3]. This issue of gender and race disparity is complex and influenced by many factors ranging from individual to community socio-cultural factors.

Gender differences can arise due to physical and psychological factors, as well as overt discrimination, socio-economic positioning, and limited access to resources. Research suggests that there may be gender differences that could potentially impact the performance of females compared to males [4]. On the other hand, studies have also demonstrated that female students generally excel in creative performance and psychomotor skills [5]. Also, it has been found that female learning performances improve when educational tools address their interests [6]. Female students tend to have more interest when the educational setting allows them to progress at their own pace and engage in their learning [7], which are two of the demonstrated characteristics of AR. On the other hand, males have an advantage over females in aspects of spatial ability-related tasks [8]. Thus, the two genders depict different qualities that can contribute towards career selection, and educational tools should be designed to facilitate an interest in genders to select careers in STEM fields.

The existence of a gender gap in STEM fields highlights the importance of finding new and effective ways to engage and empower female students. This can be done by encouraging females to pursue STEM education, creating inclusive workplaces, and providing professional development opportunities [9]. Efforts to address this gap have evolved to include innovative approaches, such as educational interventions that leverage emerging technologies in numerous fields associated with STEM.

Among these emerging technologies, Augmented Reality (AR) has been acknowledged as a practical and complementary teaching tool, offering significant enhancements to traditional teaching methods [10]. As a transformative tool, AR is known for its interactive and immersive features, and it has the potential to revolutionize the education of fields supporting STEM [11]. AR blends virtual and real worlds by overlaying virtual (computer-generated) information onto the real world [12]. Moreover, studies have shown that AR technology has increased participant engagement and satisfaction [13]. The potential of AR goes beyond its technological capabilities and has the promise to foster inclusivity and accessibility, especially for underrepresented groups such as females in STEM [14]. AR allows participants to progress at their own pace, and it has the potential to enhance female participation in STEM fields.

Therefore, this research focuses on answering the following five research questions (RQ):

- $RQ_1$: Are female students familiar with AR?
- $RQ_2$: What is the initial impression of female students about AR?
- $RQ_3$: What challenges do female students encounter while using AR for STEM education?
- $RQ_4$: Are female students interested in using AR for STEM education for a more extended period?
- $RQ_5$: What is the potential of AR to enhance learning and education among female students?

## Literature Review

Females in the STEM fields face significant underrepresentation and account for less than a quarter of the workforce in STEM occupations [15]. This highlights the importance of targeted efforts to address the challenges faced by underrepresented groups in STEM fields. It's not just for the sake of fairness, but diversity is essential to the growth of the industry. Therefore, efforts should be made to address the unique hurdles that female Hispanics encounter in STEM [16] to reduce the gender gap.

In past years, research projects have highlighted the benefits of combining traditional teaching methods with computer technology in education [17]. An example of this technology is Augmented Reality (AR). AR allows the user to see and interact with computer-generated information overlayed in the real world. AR has been recognized as a practical and supplementary teaching tool that can greatly improve traditional teaching methods [10]. AR can be used as an interactive tool that combines the real world with the digital world to create flexible learning and enrich educational contexts that help the growth of twenty-first-century skills [18].

It has been found that students and teachers may have a fair knowledge of AR, but mainly regarding the term and not the possible uses [19]. The students' attitudes toward AR as a tool in their learning environment indicate that AR has great potential as an effective tool for teaching, as it generates positive feelings of enthusiasm [19]. According to Hartless (2020), AR technology was found to be more effective than traditional paper-based methods in assessing building design [13]. Participants also reported higher engagement and satisfaction levels when using AR technology [13]. Thus, AR has the potential to help students explore, motivate, and excite them by modeling the real world and requiring interaction as part of the environment [18].

At the same time, on the one hand, AR enables learners to learn through active participation at their own pace, using a constructivist approach that involves interacting with virtual objects. On the other hand, AR environments may require students to use and combine various complex skills such as spatial navigation, collaboration, problem-solving, technology manipulation, and mathematical estimation, and this can be challenging for students who lack these essential skills [20]. As Research indicates that females may exhibit differences in learning preferences and performance compared to their male counterparts [4]. Research shows that while females perform better in creative and psychomotor tasks, they face difficulties in spatial ability tasks[8].

Thus, given the perceptional differences and strengths of each gender, the research determined the perceptions of Hispanic female high school students towards AR and its potential use in educational settings for a significant time.

## Research Methodology

To determine how female Hispanic high school students perceived AR in educational setting, a pre-experimental research design (specifically a one-shot case study methodology) was used in the setting of a summer camp specifically for Hispanic high school students. The one-shot case study methodology consists of a single participant group exposed to an experimental treatment or intervention, followed by an observation or measurement [21]. One of the method’s limitations is that it lacks a control group to compare and record differences or contrasts [22]. Even with the weakness, this methodology was used as it was best suited for research objectives. Since a control group was not required, a post-test was only needed to be administered to a single group.

The following is the information regarding the one-shot case study methodology:

a. Single Participant Group: Included female Hispanic high school students from rural areas. This demographic was chosen to address the underrepresentation of females, particularly those from minority ethnical backgrounds, in STEM fields.

b. The Model: A 3D bridge model was developed and experienced in the AR environment. The 3D bridge model was composed of a slab and columns. The concrete slab was supported by two concrete, two steel, and two wooden columns. This was done to allow students to determine the differences in columns and experience the material differences in an AR environment.

c. Setting up the AR and Pilot Test: Participants were introduced to AR using the Trimble XR-10 with HoloLens 2. The choice of Trimble XR-10 with HoloLens 2 as the AR device was made because it has a 43-degree field-of-view (among the highest currently commercially available devices), integrates hand and eye tracking sensors, and provides access to Trimble Connect for interaction with 3D models [23].The researchers pilot-tested the model, and modified challenges related to light sensitivity and menu control within the AR environment.

d. Experimental Treatment: At the beginning of the experiment, an introductory video was shown to the participants. The video demonstrated the basic controls and gestures used in Trimble XR-10 with HoloLens 2. After watching the video, the participants were guided through the model's launch through the navigation menu and taught basic commands. The experimental treatment was conducted in a controlled environment (Classroom). During the AR experience, students were provided with guidance and advised to be cautious while moving around to avoid accidents. The main focus was to ensure a smooth user experience. The equipment requires calibration when users are changed, and therefore, some students need to calibrate their devices to experience the AR environment accurately.

e. Post-test: Immediately after the experience in the AR environment, the participants were asked to complete an online survey that measured their experiences and perceptions. The online survey was hosted in Qualtrics. The survey consisted of two sections: participant demographics and AR use perceptions. Within these sections, the instrument had fifteen questions (three open-ended, and twelve remaining closed). For this study, only fourteen questions are discussed. Closed questions were used because they facilitate the quantitative analysis of the collected data [24], and the two open questions were used to gather subjective opinions and thoughts from participants, providing more in-depth and comprehensive information

e. Variables: The research variables were analyzed using the AR via Trimble XR-10 with HoloLens (Table 1) with a description of measurement type.

Table 1. Research Variables

| RQ | Variable | Short Description | Measure |
|---|---|---|---|
| 1 | Familiarity | Assesses participants' familiarity with the Trimble XR-10 with HoloLens 2 after their first interaction. | Closed (Yes/No) |
| 2 | Initial impression | Assesses participants' initial impressions of the Trimble XR-10 with HoloLens 2 after their first interaction. | Closed (Likert scale of 1 to 5) |
| | Participants' Impressions | Assesses participants' impressions after their first interaction. | Open (Pick from a list or list the answer) |
| 3 | General Challenges | Captures whether or no participants' experiences while using Trimble XR-10 with HoloLens 2 | Closed (Yes/No) |
| | | Captures the challenges encountered while using Trimble XR-10 with HoloLens 2. | Open (List the answer) |
| | Challenges: Navigating the menu | Captures the challenges of interacting with the model in the AR environment. | Closed (Yes/No) |
| | Challenges: Moving the model | | Closed (Yes/No) |
| | Challenges:Rotating the model | | Closed (Yes/No) |
| | Challenges: Resizing the model | | Closed (Yes/No) |
| 4 | Opportunities | Captures participants' interest in it for a longer duration | Closed (Yes/No) |
| 5 | Understanding/ Learning | Assesses participants' understanding after their first interaction. | Closed (Yes/No) |
| | Educational Potential | Captures participants' opinions of the potential of AR to enhance learning and education | Closed (Yes/No) |

f. Analyses: The data were downloaded, and Excel was utilized to conduct analyses and visually represent the findings.

## Results and Discussion

The survey included the responses of the five (5) students who participated in the summer camp. Therefore, the results presented in this paper are intended to serve as a starting point to introduce AR to female high school students and are not intended to be generalized to the complete population. All the participants were female Hispanic high school students. Eighty percent (80%) of the participants were fourteen (14) years old, and twenty percent (20%) were eighteen (18) years old.

Female students' familiarity with AR ($RQ_1$):
Sixty percent (60%) of the participants expressed that they were not familiar with augmented or virtual reality devices previously, while forty percent (40%) affirmed having experience with such technology. This result aligns with the literature, which indicates that students may have limited knowledge of AR, mainly regarding the term and not the actual uses of the hardware [19]. Furthermore, it highlights the importance of tailoring the summer camp to participants' different levels of familiarity with AR and leveraging existing AR knowledge to address potential barriers for novice users and effectively introduce AR for STEM education.

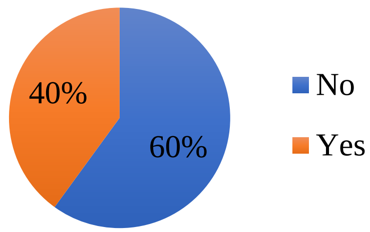



Figure 1. Familiarity with AR tools

Initial impression of female students about AR ($RQ_2$):
The responses' distribution regarding the initial experience with the AR indicates a mixed sentiment among participants, with varying degrees of satisfaction with their initial encounters. Twenty (20%) of participants indicated having a "Very good" experience, forty percent (40%) of participants had a "Good" experience, and forty percent (40%) of participants had an "Average" experience (Figure 2). These results suggest that female students may need additional support in AR use, particularly when it comes to spatial ability-related tasks. Although Munion et al. (2019) do indicate the gender differences in aspects of spatial ability-related tasks, and the preliminary findings from the research do support it, future studies still need to explore if the findings are generalizable and only applicable to female students and not male students.

AR use can be impacted by multiple aspects such as visual quality, interactivity, immersive reality, ease of use, and others. The researchers asked respondents about the aspects of the AR experience that stood out. About Seventy-five percent (75%) of the participants identified "*Interactivity*" as the standout aspect, while twenty-five percent (25%) of the participants highlighted "*Visual quality*"(. Figure 3). Interactivity and visual quality were the two most important things for female high schoolers when they're interacting in a 3D model using AR. It is important to note that none of the respondents selected *immersive reality* and *ease of use* as the AR aspects that stood out.

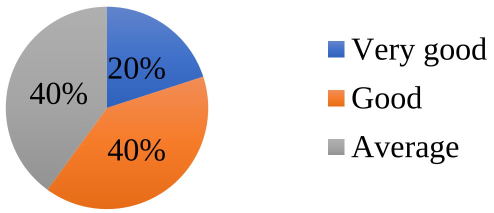
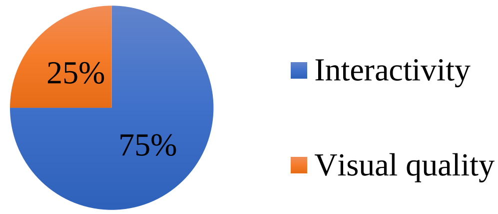



Figure 2. Initial experience




. Figure 3. Participants' impression

Challenges female students encountered while using AR for STEM education ($RQ_3$)
The participant's responses regarding challenges encountered while using the AR indicated that sixty percent (60%) of the participants did not face general challenges, while forty percent (40%) of the participants acknowledged experiencing some level of difficulties during their use of the AR(Figure 4). This could be due to spatial navigation skills needed in AR [20]. In the open-ended question, students indicated that the major challenge in the AR was grabbing objects. Therefore, if AR is to be used for STEM education effectively, before focusing on the STEM content, mentoring should be provided to the students so they can efficiently interact in the environment.

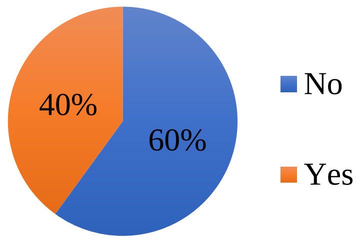


Figure 4. Challenges encountered.

In addition to the questions regarding challenges encountered by the participants, four additional questions regarding interaction with the AR were asked. These questions addressed participants' experiences navigating the menu, moving the model, rotating the model, and resizing the model.

For the question regarding "*Menu navigation*," forty percent (40%) of participants finding it easy, twenty percent (20%) of participants finding it difficult, and forty percent (40%) of participants needed some time, as shown in Figure 5. This diversity of responses suggests that some female students had difficulties using the AR menu. This could be because the interaction with the AR menu is different than interacting with menus on a computer and/or hand-held device. Alternative explanation could be that "*Menu Navigation*" was the first set of experiences encountered by the respondents. In addition, very limited students had experiences with VR games and other environments that could have potentially familiarized them with the toolset.

Regarding the ability to "*Moving the 3D model*" (supported by the hands-on activity) from side to side, eighty percent (80%) of participants confirmed that they could, while twenty (20%) of participants indicated that they could not (Figure 6). This suggests that a significant majority of participants were able to complete this task with ease, implying that most participants felt comfortable and confident when handling the Bridge Model after being challenged by navigating the AR menu. This could be related to multiple reasons such as the 3D Bridge Model design or AR user-friendly move interface, among others.

Regarding the ability to "*Rotating the 3D model*" (supported by the hands-on activity) eighty percent (80%) of the participants responded they were able to, while twenty percent (20%) of the participants indicated they had some trouble rotating the 3D model (Figure 7).

Regarding the question about "*Resizing the 3D model*", all participants were able to make the model bigger/smaller. This increased ability of female students to interact with the AR tool, beginning with only forty percent (40%) of them finding it easy to navigate to one hundred percent (100%) of them being able to resize the model is particularly interesting because it shows that the female students have a swift learning curve allowing them to eliminate all of the challenges to be able to focus on the STEM learning.

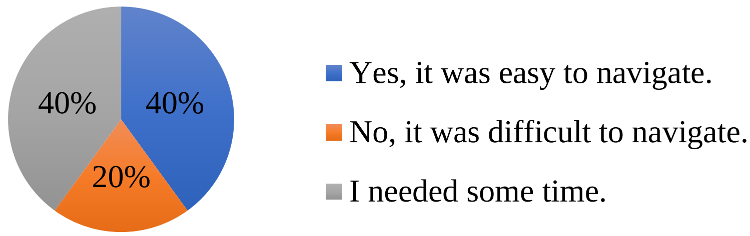


Figure 5. Navigation

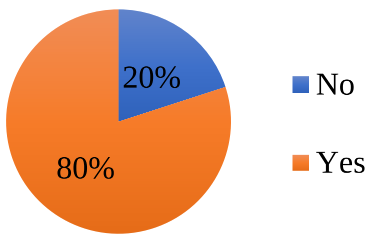


Figure 6. Moving the model

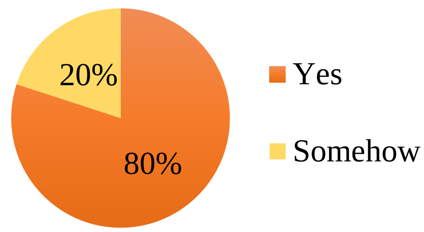


Figure 7. Rotating the model

Female students interested in using AR for STEM education for a longer period ($RQ_4$):
Participants indicated their willingness to interact with the AR tool for a longer duration if given the opportunity (Figure 8). Fifty percent (50%) of participants expressed a definite interest with a "Yes," while the other fifty percent (50%) of respondents indicated a level of uncertainty with a "Maybe." This suggests enthusiasm and curiosity among half of the participants regarding an extended experience with AR, and the other half not opposed to it.

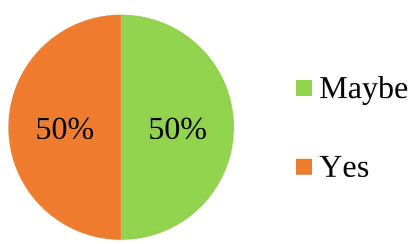


Figure 8. Opportunity for a longer duration

The potential of AR to enhance learning and education among female students ($RQ_5$):
The responses to whether the "*AR Enhanced their Understanding or Learning*" were very positive, with fifty percent (50%) of participants responding "Yes, significantly," and fifty percent (50%) of participants choosing "Yes, slightly" (Figure 9). Regarding the "*Potential of AR to Enhance Learning and Education*," all participants expressed a positive view, stating "Yes." The general agreement on the potential of AR to enhance education and learning shows that female Hispanic students see it as a valuable tool for education, which aligns with the findings of another where both teachers and students were excited after using AR materials, and recognizing

its potential in teaching and learning, and their desire to see it integrated into lessons and learning environments [19].

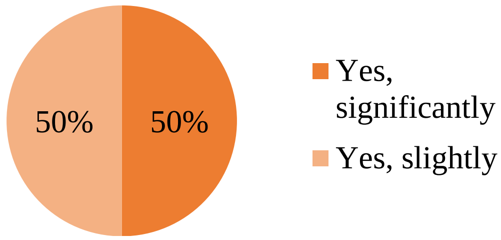



Figure 9. Enhancing understanding/learning

**Summary**

In summary, based on the data collected from the participants during the summer camp, the analysis of the AR experiences provides valuable insights into several aspects such as female students' familiarity with AR, their initial impression of AR, challenges they encountered while using AR for STEM education, their interest in using AR for STEM education for a longer period, and the potential of AR to enhance their learning and education.

The results indicate that sixty percent (60%) of participants were unfamiliar with augmented or virtual reality devices, and forty percent (40%) had some prior experience. Initial impressions of the AR varied, with twenty percent (20%) having a "Very good" experience, forty percent (40%) having a "Good" experience, and forty percent (40%) having an "Average" experience.

Notably, the majority identified "Interactivity" as the standout aspect of the AR tool, emphasizing its importance in their overall impressions. Collectively these insights collectively underscore the positive reception of the AR Tool among the participants.

Most users had positive experiences, while some faced some challenges. For example, navigation experiences showed that forty percent (40%) found menu navigation easy, twenty percent (20%) encountered difficulties, and forty percent (40%) needed some time. However, eighty percent (80%) of participants were able to move and rotate the "3D Bridge Model" successfully, and all participants were able to resize the "3D Bridge Model.

The response of participants regarding the use of AR Tool demonstrated a positive impact on understanding and learning, with fifty percent (50%) reporting a significant enhancement and the rest indicating a slight improvement. Also, all participants agreed on the e potential impact on learning and education, and fifty percent (50%) expressed a definite interest in trying it for a longer duration,

The study's results indicate that the AR Tool was well-received by the participants, who appreciated its interactivity and believed it had the potential to improve learning and education. The findings offer valuable insights for the further advancement and exploration of augmented reality tools in educational contexts.

## Limitations and Future Research

The study involved a small sample size and, therefore, limited the generalizability of the findings to a broader population. Further, the perspectives presented in this research were obtained after a single session of approximately 15 minutes in the AR. Multiple sessions and/or longer interactions might change the participants' perspective. In addition, the participants were from a very specific demographic group; therefore, the pilot study's findings should not be extrapolated to other demographic populations. Therefore, the results presented are based on a self-report survey instrument.

Based on the findings of this pilot study, future studies could determine if the findings hold true for a broad range of the population and the extent of gender perceptional differences. Future studies could also allow longer interaction time and investigate it's impact on STEM learning.. Two different methodologies could be considered: either a single group with pre- and post-tests, or an intervention and control group to evaluate the impact of AR on learning STEM content compared to traditional teaching methods. Longitudinal studies could also be conducted to track the experiences of female Hispanic users and create a model to guide users in implementing different concepts. Finally, exploring the learning curve of female Hispanic users with AR devices could help assess usability.

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## Reference

[1] M. V. Alfred, S. M. Ray, and M. A. Johnson, "Advancing Women of Color in STEM: An Imperative for U.S. Global Competitiveness," Advances in Developing Human Resources, vol. 21, no. 1, pp. 114–132, Feb. 2019, doi: 10.1177/1523422318814551.

[2] M. T. V. Taningco, A. B. Mathew, and H. P. Pachon, "STEM Professions: Opportunities and Challenges for Latinos in Science, Technology, Engineering, and Mathematics. A Review of Literature," Tomas Rivera Policy Institute, Apr. 2008. Accessed: Jan. 04, 2024. [Online]. Available: https://eric.ed.gov/?id=ED502063

[3] NGCP, "The State of Girls and Women in STEM," 2023. Accessed: Jan. 04, 2024. [Online]. Available: https://ngcproject.org/resources/state-girls-and-women-stem

[4] A. Brem, P. M. Bican, and C. Wimschneide, Gender Differences in Technology and Innovation Management. De Gruyter Oldenbourg, 2020. Accessed: Jan. 22, 2024. [Online]. Available: https://www-degruyter-com.libweb.lib.utsa.edu/document/doi/10.1515/9783110593952/html

[5] N. Huang, Y. Chang, and C. Chou, “Effects of creative thinking, psychomotor skills, and creative self-efficacy on engineering design creativity,” Thinking Skills and Creativity, vol. 37, p. 100695, Sep. 2020, doi: 10.1016/j.tsc.2020.100695.
[6] I. Heemskerk, G. ten Dam, and W. Admiraal, “Gender Inclusiveness in Educational Technology and Learning Experiences of Girls and Boys,” Journal of Research on Technology in Education, vol. 41, no. 3, pp. 253–276, 2009.
[7] M. Samuelsson and J. Samuelsson, “Gender differences in boys’ and girls’ perception of teaching and learning mathematics,” Open Review of Educational Research, vol. 3, no. 1, pp. 18–34, Jan. 2016, doi: 10.1080/23265507.2015.1127770.
[8] A. K. Munion, J. K. Stefanucci, E. Rovira, P. Squire, and M. Hendricks, “Gender differences in spatial navigation: Characterizing wayfinding behaviors,” Psychon Bull Rev, vol. 26, no. 6, pp. 1933–1940, Dec. 2019, doi: 10.3758/s13423-019-01659-w.
[9] Clara Piloto, “The Gender Gap in STEM | MIT Professional Education.” Accessed: Jan. 31, 2024. [Online]. Available: https://professionalprograms.mit.edu/blog/leadership/the-gender-gap-in-stem/
[10] Á. Di Serio, M. B. Ibáñez, and C. D. Kloos, “Impact of an augmented reality system on students’ motivation for a visual art course,” Computers & Education, vol. 68, pp. 586–596, Oct. 2013, doi: 10.1016/j.compedu.2012.03.002.
[11] A. Pregowska, K. Masztalerz, M. Garlińska, and M. Osial, “A Worldwide Journey through Distance Education—From the Post Office to Virtual, Augmented and Mixed Realities, and Education during the COVID-19 Pandemic,” Education Sciences, vol. 11, no. 3, Art. no. 3, Mar. 2021, doi: 10.3390/educsci11030118.
[12] M. Fuge, M. E. Yumer, G. Orbay, and L. B. Kara, “Conceptual design and modification of freeform surfaces using dual shape representations in augmented reality environments,” Computer-Aided Design, vol. 44, no. 10, pp. 1020–1032, Oct. 2012, doi: 10.1016/j.cad.2011.05.009.
[13] J. F. Hartless, S. K. Ayer, J. S. London, and W. Wu, “Comparison of Building Design Assessment Behaviors of Novices in Augmented- and Virtual-Reality Environments,” Journal of Architectural Engineering, vol. 26, no. 2, p. 04020002, Jun. 2020, doi: 10.1061/(ASCE)AE.1943-5568.0000396.
[14] M. Akçayır and G. Akçayır, “Advantages and challenges associated with augmented reality for education: A systematic review of the literature,” Educational Research Review, vol. 20, pp. 1–11, Feb. 2017, doi: 10.1016/j.edurev.2016.11.002.
[15] I. D. M. Aripin, E. M. A. Zawawi, and Z. Ismail, “Factors influencing the implementation of technologies behind industry 4.0 in the Malaysian construction industry,” in MATEC Web of Conferences, EDP Sciences, 2019, p. 01006.
[16] A. Chapman et al., “‘Nothing is impossible’: characteristics of Hispanic females participating in an informal STEM setting,” Cult Stud of Sci Educ, vol. 15, no. 3, pp. 723–737, Sep. 2020, doi: 10.1007/s11422-019-09947-6.
[17] J. M. Durbin, “The Benefits of Combining Computer Technology and Traditional Teaching Methods in Large Enrollment Geoscience Classes,” Journal of Geoscience Education, vol. 50, no. 1, pp. 56–63, Jan. 2002, doi: 10.5408/1089-9995-50.1.56.
[18] G. Papanastasiou, A. Drigas, C. Skianis, M. Lytras, and E. Papanastasiou, “Virtual and augmented reality effects on K-12, higher and tertiary education students’ twenty-first century skills,” Virtual Reality, vol. 23, no. 4, pp. 425–436, Dec. 2019, doi: 10.1007/s10055-018-0363-2.

[19] I. Sural, “Augmented Reality Experience: Initial Perceptions of Higher Education Students,” International Journal of Instruction, vol. 11, no. 4, pp. 565–576, Oct. 2018.
[20] H.-K. Wu, S. W.-Y. Lee, H.-Y. Chang, and J.-C. Liang, “Current status, opportunities and challenges of augmented reality in education,” Computers & Education, vol. 62, pp. 41–49, Mar. 2013, doi: 10.1016/j.compedu.2012.10.024.
[21] T. E. Dawson, “A Primer on Experimental and Quasi-experimental Design,” Jan. 1997. Accessed: Dec. 06, 2023. [Online]. Available: https://eric.ed.gov/?id=ED406440
[22] B. Ohlund and C. Yu, “Threats to validity of Research Design.” Accessed: Jan. 29, 2024. [Online]. Available: https://web.pdx.edu/~stipakb/download/PA555/ResearchDesign.html
[23] “Trimble XR10 with HoloLens | Mixed Reality Field Solutions.” Accessed: Jan. 26, 2024. [Online]. Available: https://www.buildingpointsoutheast.com/solutions/trimble-xr10-with-hololens
[24] R. B. Johnson and L. Christensen, Educational Research: Quantitative, Qualitative, and Mixed Approaches. SAGE Publications, 2020.