Evaluating students’ behavioral intention and system usability of augmented reality-aided distance design learning during the COVID-19 pandemic

Hsinfu Huang1 · Guiru Liu1

Accepted: 15 September 2022
© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2022

Abstract
Because of the impact of the COVID-19 pandemic, learning modes had to change. This study applied augmented reality (AR) technology to improve the learning experience of product styling design students in a distance learning environment. An AR-aided learning interface combined with a distance learning concept was constructed to enhance students’ content knowledge and communication between teachers and students. This study analyzed students’ attitudes and behavioral intentions toward the technology acceptance model for this AR-aided distance learning interface. Additionally, a system usability scale was used to examine the usability level of this interface. The results demonstrated that learning content directly affected distance interaction, and perceived ease of use was an essential mediating variable. Furthermore, three-dimensional (3D) visualization was a predictive factor that directly affected students’ attitudes toward AR use. Students had positive attitudes toward the AR-aided learning interface, and their feedback indicated that 3D visualization stimulated their learning motivation and enhanced their behavioral intentions. Overall, the AR-aided styling learning interface supported the distance learning of product styling design students and provided teachers and students with a valuable learning communication channel during the COVID-19 pandemic.

Keywords COVID-19 pandemic · Augmented reality (AR) · Distance learning · Behavioral intentions · System usability

1 Introduction
The COVID-19 pandemic has affected people’s daily lives and altered work patterns [4, 34, 52] in numerous industries, including manufacturing, technology, education, arts, and cultural industries. People’s jobs were no longer confined to the same space, and distance contact and communication became notable work features. Furthermore, to inhibit virus transmission, multiple countries’ centers for disease control have recommended limiting domestic and international travel and adopting quarantine and social distancing policies to reduce crowd sizes. Thus, people’s contact methods had to change. The most common method of communication became online video calls. Watson et al. [64] indicated in their study on the COVID-19 pandemic that during periods of limited activity, digital communication technology, especially online video communication, became increasingly essential to people’s work and family lives.

The pandemic rapidly and markedly affected education because many students were required to learn from home. In-person learning was replaced by digital distance learning [3, 50]. Dhawan [25] posited that because of COVID-19’s effect on education, distance learning has become a necessary learning mode. Students are no longer limited to in-site learning at school, and distance learning has played an essential role in the pandemic response. Distance learning ensured the continuity of students’ learning and improved learning opportunities for students required to remain at home. However, it also created new learning concerns (Contreras, [19]), particularly regarding the limitations of learning tools. For example, students of numerous backgrounds were, for the most part, learning through laptops, which altered the flexibility and experience of learning.

In the product design field, social distancing and crowd limitation policies not only affected students’ learning...
environment but also altered the methods through which group work was conducted, especially in styling design education. In such courses, students learn from visuals of stereoscopic objects, noting their appearance, detailed features, and style. However, during distance learning, if a professor only uses oral narrative to describe and explain abstract concepts such as relevant shape design or style, students may not understand they styling characteristics the teacher aimed to convey. Additionally, general distance learning mainly focuses on videos and electronic texts, which inadequately display styling details compared with an in-person course. Therefore, the existing distance learning model was insufficient for styling design education, and students often had a poor learning experience. Related research on multimedia flipped classrooms emphasized that appropriate visual and auditory stimuli should be presented to enhance students’ understanding and participation in the learning process [62]. Additionally, visual and interactive content has improved students’ motivation, attitude, and outcomes (Iftene & Trandabă [38], 54).

The COVID-19 pandemic provided an opportunity for students and educators to adapt and develop diverse learning practices (Loukatos, [45]), and promoted the widespread use of distance learning. The accessibility, usability, and acceptability of learning interfaces have garnered research attention. Diversified learning experiences and effective learning interfaces are essential for students, and related topics are trends in the development of assisted learning technology. Augmented reality (AR) is a type of real-time visualization in information and communication technology that has been actively and widely used in many fields, including medicine, entertainment, education, architecture, and fashion design [13, 17, 42, 66]. AR provides stereoscopic visual guidance integrated into the real environment and can present vital information through a three-dimensional (3D) display. Therefore, AR technology is often used by smart institutions, such as product development centers, medical training institutions, and multimedia flipped learning classrooms. Cai et al. [15] indicated that AR technology can combine virtual objects with real environments to create more realistic and interactive learning environments, which can improve the deficiencies of the actual environment. Additionally, the advantage of applying AR technology to learning is that the constructed interactive learning environment can effectively arouse students’ interest in learning and increase their level of participation. Contero et al. [18] indicated that the 3D stereo imaging presented by AR could improve students’ understanding of engineering components. His study emphasized that incorporating AR into the learning process increased student interaction, and students had positive learning attitudes and experiences. Choi et al. [17] indicated that AR was an effective learning tool and that its 3D imaging technology could impart vital knowledge to enhance students’ learning. Therefore, using AR technology in education can encourage students to concretize and visualize learning concepts as well as strengthen their motivation to learn.

Distance learning has become a necessary education method because on-site learning has not been possible during various stages of the COVID-19 pandemic. However, distance learning materials based on current modes of videotelephony are mostly presented as flat images, which limit the product styling design learning experience because conveying the characteristics of stereoscopic objects is difficult. Therefore, the application of AR technology to enhance the learning experience of styling design students, especially during the COVID-19 pandemic, has developmental advantages and is practical. In this study, a distance learning framework of styling design based on AR technology was developed. A 3D image interface could reduce the knowledge gap and increase communication between the teacher and students. The system usability scale (SUS) and technology acceptance model (TAM) of this interface were examined to understand students’ degree of usability and attitude toward this interface. The research results promote learning communication channels and virtual technology–aided learning experiences during and possibly after the COVID-19 pandemic.

2 Literature review

2.1 Distance learning under the influence of the COVID-19 pandemic

Distance learning refers to learning through relevant online equipment when a physical distance exists between the student and teacher (Simonson, [57], 3, 41). Over the past few years, such learning has changed the concept of traditional education and created a learning environment that is not limited by distance, space, or time. Caliskan et al. [16] indicated that the main service targets of distance learning are students who cannot participate in in-person courses because of various reasons. Most students can use mobile communication devices to study at home and freely choose a suitable learning environment, such students need not be restricted to traditional educational institutions or classrooms. Compared with traditional on-site learning methods, distance learning is more convenient, flexible, and adaptable. Students’ demand for personalized learning is increasing, and distance learning can adapt to the individual needs of students. Distance learning is growing rapidly at a rate of 19% per year [58], and many educational institutions and schools provide increasingly diversified online courses and opportunities. Teachers and students can interact with each other at any time and place through the internet. However, distance learning also has some limitations, including usability concerns...
that must be addressed. Some studies have indicated that creativity, interactivity, and connectivity are essential to distance learning and that the development of a student-centered framework can maximize its effects [14, 25].

Although distance learning is not a new concept, it became vital during the COVID-19 pandemic [5, 30]. The pandemic has required students to switch from traditional on-site group learning to individual distance learning. The effect of this change was not limited to students, teachers could prepare learning materials more flexibly, promoting the use of digital teaching materials [20]. Elfirdoussi et al. [30] indicated in an evaluation of distance learning in higher education during the COVID-19 pandemic that current distance learning is not more interesting than traditional learning. To promote the overall effect of distance learning, evaluating the use of flexible technologies, computer devices, and applications to enhance the learning process and interactions between teachers and students is necessary. Although distance learning has been an effective solution for continuing learning during the COVID-19 pandemic, teachers must also actively attempt to create useful and engaging learning material to increase students’ success [53]. Sandani et al. [58] applied distance learning to the medical field, and the results demonstrated that the existing distance video learning method could not provide sufficient interaction for students, despite students’ expressing interest in distance learning in the future. They indicated that more suitable technology would improve the integrity and interactivity of the distance learning environment.

2.2 Educational applications of AR

Given the maturity of AR technology and the popularity of smart devices, the applicability of AR in various educational fields is unequivocal [13, 42]. For example, AR has been actively applied within the medical education and training field. Zorzal et al. [66] indicated that AR plays a vital role in the auxiliary medical environment, especially for laparoscopic surgery. AR can display patients’ data interface without hindering surgeries and promote communication between members of the surgical team to reduce surgeon fatigue. The application of AR is increasing rapidly in the industry, improving the performance of relevant personnel, especially in situations in which reality cannot be realistically represented, and facilitating dangerous training processes [15].

Similarly, according to research, students’ motivation and attitude improved when AR technology was applied in science classes. Sahin and Yilmaz [54] applied AR technology to a secondary school astronomy curriculum. Students in the experimental group learned astronomy through AR textbooks, and the control group used traditional learning methods. The results demonstrated that the experimental group had greater learning motivation and attitudes than the control group did, and the students indicated that the actualization of abstract concepts through AR made the course content more interesting and easier to understand. Additionally, the chemical structure of atoms in the real world cannot be observed with the naked eye and is difficult to simulate. Thus, Cai et al. [15] simulated the structural formation of atoms and molecules through AR and indicated that the interactive process of AR can promote students’ understanding of the atomic world. AR can also be applied in engineering education, as demonstrated in a study by Kaur et al. [40], whose results illustrated that visual 3D displays helped students learn materials for their electronic engineering class. The AR learning environment has received positive feedback in terms of student attention, self-confidence, and satisfaction.

The application of AR also has a considerable impact on humanities and arts-related courses, and enables students to obtain greater learning benefits [32]. For example, Serio et al. [55] introduced AR technology into art classes to explain Renaissance artwork. The results demonstrated that learning through AR could reduce students’ cognitive burden and improve their memory. Different from static artwork pictures, the addition of AR to the learning materials could fully present 3D virtual objects and interactive learning content. Eldokhny and Drwish [29] explored the effectiveness of distance learning during the COVID-19 pandemic in the context of AR technology. The results emphasized that AR-based visual stereo enhancement had potential for distance learning. Therefore, AR technology has been widely used in various educational domains and provides a virtual interactive learning framework that differs from traditional learning media. Such technology can be integrated into the real environment and provides students with the opportunity to have many unique learning experiences.

2.3 Technology acceptance model for an AR learning interface

AR technology has been practically applied to learning and training, and it integrates virtual and tangible information in the learning environment. In this study, an AR-aided styling learning interface (ARSLI) was designed for education during the COVID-19 pandemic. This AR learning interface was combined with an internet-based distance learning environment. Students could understand how classic product styling design works and observe the characteristics of various products through AR interaction. This learning interface could serve as a communication bridge between the teacher and students and promote students’ understanding of concrete modeling appearance and abstract design style. However, the usability of the interface, students’ attitudes toward the use of technology in this manner, and related influencing variables warranted discussion. According to relevant
research, the TAM could enable a structured analysis and effective exploration of the relationship between users’ attitudes and intentions [21, 63], Bertrand & Bouchare, [8]; [49]. The TAM is often used to explain users’ attitudes and behavioral intentions toward new information technology or devices, including e-learning, virtual reality, AR, and social networks [27, 37, 39, 44, 46, 48]. Manis and Choi [47] investigated consumer acceptance of virtual reality devices by using the TAM. Relevant variables were incorporated into a structural equation model to predict future use and purchase intention. Some researchers have attempted to apply the TAM to investigate attitude toward the use of AR [6, 36, 43]. This demonstrates that the TAM is an effective method of exploring user attitudes toward virtual technology and investigating related variables. For example, Ibili et al. [36] investigated mathematics teachers’ level of acceptance and intention to use the Augmented Reality Geometry Tutorial System (ARGTS). The results demonstrated that perceived ease of use (PEU) had a direct effect on perceived usefulness (PU); however, PEU had no direct effect on attitude toward use (ATU). The researchers emphasized that their findings are helpful in understanding teachers’ attitudes and acceptance of AR. However, most related research topics have been examined in normal learning environments. Considerably less attention has been devoted to the application of AR interfaces in distance learning environments, especially in the context of the COVID-19 pandemic.

Additionally, Davis [22] emphasized that for numerous types of technology, relevant external variables should be proposed to better explore users’ acceptance model. In this study, the main external variables included stereo visualization (SV), distance interaction (DI), and learning content (LC). Furthermore, this research used path analysis to explore the effects of various external variables on perceived usefulness (PU), perceived ease of use (PEU), attitude toward use (ATU), and behavioral intention to use (BIU) to further understand students’ use attitudes and intentions toward using an ARSLI. This research focused on students’ acceptance, use of feedback, and related influencing variables for the application of an AR learning interface in a product styling design course. Moreover, the path relationship of the learner’s technological acceptance model was presented.

3 Methods

In this study, a TAM of an ARSLI was used as a research hypothesis framework, and the influence of various variables, including external variables and TAM basic variables, was explored through path analysis. Students were invited to participate in a survey experiment related to this TAM. Furthermore, the usability of this learning interface was evaluated through the SUS to understand the students’ system usability score in the ARSLI.

3.1 Participants

A total of 120 college students from the department of industrial design were invited to participate in this experiment. Participants had an average age of 20.68 years (SD = 1.62), and 52 of them were women. They all had basic design-related knowledge and experience using technological products, such as smartphones and tablets. A total of 48 participants had experience in AR technology, such as AR game software, and all participants experienced distance learning during the COVID-19 pandemic. The related demographic information is presented in Table 1.

3.2 Experimental stimuli

In this study, the ARSLI was the main experimental stimuli, as illustrated in Fig. 1, and participants used this learning interface in their product styling design distance course. This ARSLI was developed based on the UNITY 3D program and the Vuforia Engine. It has been widely used for the development of AR content. The materials presented

| Table 1 Demographics of participants |
|-------------------------------------|
| Item                  | Properties          | n  |
| Gender                | Female              | 52 |
|                       | Male                | 68 |
| Grade                 | Undergraduate student | 61 |
|                       | Graduate student    | 59 |
| AR experience         | Yes                 | 66 |
|                       | No                  | 54 |
through AR are compiled such that they conform to the knowledge points of styling design learning. These materials can be easily accessed and updated in similar design courses. The teacher presented the learning materials for the course through videotelephony, and students viewed the material on a laptop. A total of 18 classic product design works, some of which are presented in Fig. 2, were displayed throughout the course. These works were also used as scanning objects for the ARSLI. Participants used a smartphone loaded with the ARSLI app to scan the images, and the corresponding 3D objects appeared on the screen. Vital content knowledge, such as advanced author information, design concepts, product size, and appearance lines, were also presented. Furthermore, the ARSLI image could be rotated in 3D and enlarged. Participants could control the objects on their touch screen through gestures or virtual buttons. The ARSLI also provided a snapshot feature of the product styling features. Students could use this snapshot function to record crucial product features. Participants’ learning reactions and usage behaviors were recorded through remote video recording, and a questionnaire was distributed after participants engaged in experiential learning.

3.3 Questionnaire design

The source of all variables (constructs) in the TAM questionnaire included the features of the ARSLI, related research on AR experiential learning [13, 42, 54], Iftene & Trandabăț, [38]; [40, 65], related research on multimedia learning interfaces [9], Sung [61]; [51], a guidebook on human–computer interaction design [26, 56, 59], and related research on the TAM [22, 23, 31], Bertrnd & Bouchare, [8]; [49]. Participants rated each item on the questionnaire on a 5-point Likert scale, with scores ranging from 1 to 5 for strongly disagree, disagree, neutral, agree, and strongly agree. The description of each construct and item is displayed in Table 2. An additional 10-question questionnaire measured SUS scores for the

![Fig. 2 Learning materials of product styling design on the ARSLI. a Barcelona chair, Ludwig Mies van der Rohe, 1929; b Mae West Lips Sofa, Salvador Dali, 1972; c Hill house chair, Charles Rennie Mackintosh, 1903; d 9093 Kettle, Michael Graves, 1985 (DK Inc., [28])](image-url)
Odd-numbered questions were positive and even-numbered questions were negative [7, 11]. This questionnaire was also answered using a 5-point scale. The SUS questions are displayed in Table 3.

### Table 3  SUS questionnaire of the ARSLI

| Item                                                                 |
|----------------------------------------------------------------------|
| Q1: I think that I would like to use the ARSLI frequently            |
| Q2: I found the ARSLI unnecessarily complex                           |
| Q3: I thought the ARSLI was easy to use                               |
| Q4: I think that I would need the support of a technical person to be able to use the ARSLI |
| Q5: I found the various functions in the ARSLI were well integrated  |
| Q6: I thought there was too much inconsistency in the ARSLI          |
| Q7: I would imagine that most people would learn to use the ARSLI very quickly |
| Q8: I found the ARSLI very cumbersome to use                         |
| Q9: I felt very confident using the ARSLI                             |
| Q10: I needed to learn a lot of things before I could get going with the ARSLI |

### 3.4 Research model and hypotheses

Related research has indicated that the basic variables of the TAM include PU, PEU, ATU, and BIU [21, 23]. Bertrnd
PU and PEU may affect students’ attitude toward using technology, which in turn affects specific behaviors. PU is a measure of a user’s belief that using a particular system can improve their work performance. PEU is the degree to which the user deems the system easy to use, and this variable may affect PU. These variables determine the user’s attitude toward the use of new technologies. Moreover, the user’s ATU would eventually affect their BIU [21, 49]. Therefore, this research used the TAM as the main infrastructure, referenced related AR studies, and proposed a research model and hypotheses (H1 and H12) for the ARSLI, as depicted in Fig. 3. With SV, product styling objects are presented in 3D through AR technology. The DI refers to the interactivity and related functions on the distance learning interface. The LC refers to the styling description and materials that students can study on the ARSLI. In this research model, SV, DI, and LC were selected as external variables and combined with the basic variables of the TAM to explore user experience of and intention toward using the ARSLI. The hypotheses for each path are presented in Table 4.

### 3.5 Procedures

In this study, an experiential distance learning model was integrated into a product styling design learning course, and the ARSLI was used as the main learning tool. Participants were able to use this learning interface repeatedly. At the end of the course, all participants completed the TAM and SUS questionnaires. Additionally, the researcher prepared some open-ended questions, and participants’ feedback was recorded. The tele-video camera also recorded certain events and participants’ behaviors throughout the learning process. The experiment was performed during one 50-min class.

### 3.6 Data analysis

SPSS 22.0 and SPSS Amos 22.0 were used as the major statistical analysis tool for experimental data. The statistical analysis methods included structural equation modeling analysis (SEM), reliability analysis, validity analysis (confirmatory factor analysis), correlation analysis, and independent samples t test.

![Structural model of the research hypothesis](image)

### Table 4 Research hypotheses

| Path | Hypotheses |
|------|-------------|
| H1   | The stereo visualization (SV) on the learning interface will positively affect learning content (LC) |
| H2   | The learning content (LC) in the learning interface will positively affect distance interaction (DI) |
| H3   | The stereo visualization (SV) on the learning interface will positively affect distance interaction (DI) |
| H4   | The distance interaction (DI) on the learning interface will positively affect perceived usefulness (PU) |
| H5   | The distance interaction (DI) on the learning interface will positively affect perceived ease of use (PEU) |
| H6   | The perceived ease of use (PEU) of the learning interface will positively affect its perceived usefulness (PU) |
| H7   | The perceived usefulness (PU) of the learning interface device will positively affect attitude toward using (ATU) |
| H8   | The perceived ease of use (PEU) of the learning interface device will positively affect attitude toward using (ATU) |
| H9   | The stereo visualization (SV) on the learning interface will positively affect attitude toward using (ATU) |
| H10  | The distance interaction (DI) on the learning interface will positively affect attitude toward using (ATU) |
| H11  | The learning content (LC) on the learning interface will positively affect perceived usefulness (ATU) |
| H12  | The attitude toward using (ATU) of the learning interface will positively affect behavioral intention to use (BIU) |
4 Results

4.1 Descriptive analysis

The descriptive statistics for all constructs are presented in Table 5. The mean value of LC was lower than mean SV and DI values for the external variables. The mean for all constructs was 3.84, which indicates that on average, respondents perceived the ARSLI positively. The descriptive statistics of various grade levels and AR experience levels in each construct are depicted in Table 6. The results of the independent sample t test demonstrated that the AR experience did not affect each construct ($p > 0.05$). Significant differences primarily existed between students of different grades. The average values of students in lower grades were higher than those of students in higher grades for the SV ($t = 2.87; p < 0.01$) and ATU constructs ($t = 2.01; p < 0.05$). No significant difference in gender was noted in any construct ($p > 0.05$).

4.2 Reliability and convergent validity

The overall reliability of the TAM questionnaire was satisfactory (Cronbach’s $\alpha = 0.844$). The reliability and validity of all measurement constructs are presented in Table 7. The Cronbach’s $\alpha$ of each construct was greater than 0.7, which confirmed the TAM questionnaire’s reliability (Hair et al., 1998). Additionally, confirmatory factor analysis (CFA) was used to assess the convergent validity of each construct (Anderson and Gerbing, 1988). According to the CFA results, all factor loadings exceeded 0.7. Composite reliability (CR) and average variance extracted (AVE) were also used to assess convergence validity (Fornell and Larcker, 1981; Hair et al., 1998). Fornell and Larcker (1981) indicated that CR is the reliability component of all measurement variables and can represent the internal consistency of a construct. High reliability indicates that the consistency of these constructs is high, and the recommended value above 0.6; AVE is the average amount of variance among the indicator variables that can be explained by a construct, and the recommended value is more than 0.5. In this study, the Cronbach’s $\alpha$, CR, and AVE values of each variable were all above the recommended values (Fornell and Larcker, 1981; Sharma, 1995; Hair et al., 1998). This result revealed satisfactory convergent validity.

4.3 Discriminant validity

As revealed in Table 8, each construct had satisfactory discriminant validity. The determining criterion was that the square root of the AVE of each construct was greater than the correlation coefficient of each construct, meaning that

| Table 5 | Descriptive statistics of constructs |
|---------|-------------------------------------|
| Construct | N | Mean | SD |
| External variables | | | |
| SV | 120 | 3.94 | 0.72 |
| DI | 120 | 3.92 | 0.84 |
| LC | 120 | 3.75 | 0.81 |
| Basic variables | | | |
| PUE | 120 | 3.90 | 0.73 |
| PU | 120 | 3.73 | 0.82 |
| BIU | 120 | 3.71 | 0.94 |
| ATU | 120 | 3.91 | 0.74 |

| Table 6 | Descriptive analysis of grade and AR experience in different constructs |
|---------|--------------------------------------------------|
| Construct | Grade | N | Mean | SD | t |
| SV | Undergrad | 61 | 4.11 | 0.44 | 2.87** |
| | Grad | 59 | 3.75 | 0.88 |
| DI | Undergrad | 61 | 3.86 | 0.88 | -0.74 |
| | Grad | 59 | 3.97 | 0.80 |
| LC | Undergrad | 61 | 3.68 | 0.80 | -1.02 |
| | Grad | 59 | 3.83 | 0.82 |
| PU | Undergrad | 61 | 3.63 | 0.86 | -1.34 |
| | Grad | 59 | 3.83 | 0.76 |
| PUE | Undergrad | 61 | 3.81 | 0.71 | -1.51 |
| | Grad | 59 | 4.01 | 0.75 |
| ATU | Undergrad | 61 | 4.04 | 0.56 | 2.01* |
| | Grad | 59 | 3.77 | 0.88 |
| BIU | Undergrad | 61 | 3.78 | 0.92 | 0.77 |
| | Grad | 59 | 3.64 | 0.95 |

| Table 7 | Descriptive analysis of grade and AR experience in different constructs |
|---------|--------------------------------------------------|
| Construct | Exp | N | Mean | SD | t |
| SV | Yes | 66 | 3.94 | 0.75 | 0.23 |
| | No | 54 | 3.91 | 0.68 |
| DI | Yes | 66 | 3.91 | 0.89 | -0.16 |
| | No | 54 | 3.93 | 0.78 |
| LC | Yes | 66 | 3.69 | 0.86 | -0.91 |
| | No | 54 | 3.82 | 0.74 |
| PU | Yes | 66 | 3.75 | 0.77 | 0.36 |
| | No | 54 | 3.70 | 0.88 |
| PUE | Yes | 66 | 4.01 | 0.67 | 1.68 |
| | No | 54 | 3.79 | 0.80 |
| ATU | Yes | 66 | 3.88 | 0.81 | -0.52 |
| | No | 54 | 3.95 | 0.66 |
| BIU | Yes | 66 | 3.70 | 0.96 | -0.18 |
| | No | 54 | 3.73 | 0.91 |

*p < 0.05; **p < 0.01
4.4 Structural equation model analysis

The results of the structural equation model analysis for the ARSLI are depicted in Fig. 4. A total of six paths revealed significance in this TAM model. The LC of external variable had a significant positive effect on the DI (β = 0.56, \( t = 7.37, p < 0.01 \)), and the SV had a significant effect on the ATU (β = 0.76, \( t = 13.31, p < 0.01 \)). Additionally, four paths indicated significant effects for basic variables of the TAM. Among them, the DI had a significant effect on the PEU (β = 0.44, \( t = 5.29, p < 0.01 \)) and PEU (β = 0.24, \( t = 2.46, p < 0.01 \)), and the PEU affected the ATU (β = 0.17, \( t = 2.47, p < 0.01 \)). The BIU was mainly affected by the ATU (β = 0.44, \( t = 5.36, p < 0.01 \)). A significant path also revealed that the model’s hypothesis was supported. The path coefficient and significance of each hypothesis are presented in detail in Table 9. A fit test was performed to measure the fitness degree between the research model and actual observation data. These fit indices were required to be consistent with the recommended values in the relevant literature. In this study, all measured values were consistent with the relevant fit index; the related results are displayed in Table 10.

4.5 Effects analysis

The main effect of each construct could be divided into direct and indirect effects. According to the effect calculation result of the path coefficient, the LC directly affected the DI (direct effect = 0.56), and DI directly affected the PEU and PU. The LC had an indirect effect on the PEU and PU. The effect of DI on the PEU was greater than on PU. However, the PEU directly affected the ATU. SV had the most apparent influence on students’ ATU (direct effect = 0.76) and affected BIU (indirect effect = 0.33). The results of the direct and indirect effects of this research model are presented in Table 11.

4.6 Results of system usability scale

The results related to the original usability scores for the ARSLI are displayed in Table 12. Usability scores for each question were calculated by reducing the original scores of the odd-numbered questions by one point each and deducting the original score of each even-numbered question from 5 [7, 10, 11]. The sum of the usability scores for each question is then multiplied by 2.5 to obtain the final score of the SUS. In this study, the final SUS score of the
ARSLI was 79.35. Related research has indicated that the SUS can be divided into five grades as follows: A: 90–100, B: 80–89, C: 70–79, D: 60–69, and F: 0–59 [7, 11]. The current ARSLI SUS is in grade C, but it is quite close to a B grade. The acceptability range of ARSLI usability is between ‘good’ and ‘excellent,’ as depicted in Fig. 5. The results demonstrate that the usability level of this learning interface is acceptable and the interface is easy to use. According to the results of the independent sample t test, SUS score was not affected by the participants’ gender ($p > 0.05$), grades, or AR experience ($p > 0.05$).

5 Discussion

In response to the COVID-19 pandemic, videotelephony has replaced traditional on-site learning as the main communication channel between students and teachers in the aforementioned styling design class. During traditional

---

**Table 9** Results of the hypothesis tests

| Hypothesis | Path  | Estimate | S.E  | $t$   | P value | Standardized coefficient (β) | Result         |
|------------|-------|----------|------|-------|---------|-------------------------------|----------------|
| H1         | SV → LC | 0.02     | 0.10 | 0.16  | 0.874   | 0.02                          | Not supported  |
| H2         | LC → DI | 0.58     | 0.08 | 7.37  | ***     | 0.56                          | Supported      |
| H3         | SV → DI | 0.00     | 0.09 | 0.01  | 0.996   | 0.00                          | Not supported  |
| H4         | DI → PU | 0.23     | 0.10 | 2.46  | 0.014   | 0.24                          | Supported      |
| H5         | DI → PEU| 0.38     | 0.07 | 5.29  | ***     | 0.44                          | Supported      |
| H6         | PEU → PU| 0.08     | 0.11 | 0.67  | 0.488   | 0.07                          | Not supported  |
| H7         | PU → ATU| 0.09     | 0.05 | 1.70  | 0.089   | 0.10                          | Not supported  |
| H8         | PEU → ATU| 0.17    | 0.06 | 2.73  | 0.006   | 0.17                          | Supported      |
| H9         | SV → ATU| 0.78     | 0.06 | 13.31 | ***     | 0.76                          | Supported      |
| H10        | DI → ATU| -0.07    | 0.06 | -1.16 | 0.247   | -0.09                         | Not supported  |
| H11        | LC → ATU| 0.01     | 0.06 | 0.89  | 0.419   | 0.06                          | Not supported  |
| H12        | ATU → BIU| 0.56    | 0.10 | 5.36  | ***     | 0.44                          | Supported      |

* $p < 0.05$; **$p < 0.01$

**Table 10** Fit indices for the research model in this study

| Fit index | Recommended value | Measurement | Fitness | Source                         |
|-----------|-------------------|-------------|---------|--------------------------------|
| $\chi^2$/DF | $< 3$             | 1.426       | yes     | Hari et al. (1998)            |
| GFI       | $> 0.9$           | 0.971       | yes     | Segars and Grover (1993)      |
| AGFI      | $> 0.8$           | 0.910       | yes     | Segars and Grover (1993)      |
| RMSEA     | $< 0.08$          | 0.062       | yes     | Browne and Cudeck (1993)       |
| NFI       | $> 0.9$           | 0.944       | yes     | Bentler and Bonett (1980)      |
| CFI       | $> 0.9$           | 0.981       | yes     | Bentler (1988)                |
| IFI       | $> 0.9$           | 0.982       | yes     | Widaman and Thompson (2003)    |
distance learning, the teacher used oral or static pictures as the medium of expression to describe product styling. Because many students were often unable to immediately concretize abstract shapes or absorb the class content, they had difficulty forming corresponding styling concepts. Because of these concerns with this distance learning model, AR technology was applied to improve the distance learning experience of students in the product styling design course, and the study examined students’ attitudes toward the learning interface and system usability. The path analysis results of the research model indicated that the SV did not affect the LC (Hypothesis 1 was not supported), but it directly affected the ATU (Hypothesis 9 was supported). LC directly affected DI (Hypothesis 2 was supported), but did not affect the ATU (Hypothesis 11 was not supported). Concerning the ARSLI, the students’ attitudes were affected by the SV but not the LC. Therefore, the 3D stereo visualization feature of AR was a notable and attractive experience. Some studies have also indicated that stereoscopic AR images improve the learning experience [54, 65]. Similarly, Sumadio et al. [60] indicated that the 3D stereoscopic display mode of augmented reality combined with the real environment can present an immersive experience in a natural and realistic state. Students’ attention and learning motivation would be effectively improved. Our result also verified similar results, even for different learning subjects.

Table 11 Results of path effects between constructs

|       | SV | LC | DI | PEU   | PU   | ATU   |
|-------|----|----|----|-------|------|-------|
| SV    |    |    |    | 0.56* |      |       |
| LC    |    |    |    | 0.25**| 0.44*|       |
| DI    |    |    |    | 0.13**| 0.24*|       |
| PEU   |    |    |    | 0.04**| 0.07**|0.17*  |
| PU    |    |    |    | 0.02**| 0.03**|0.07**|0.44*  |
| ATU   |    |    |    |       |       |       |
| BIU   |    |    |    |       |       |       |

* Direct effects; ** Indirect effects; / nonsignificant path

Table 12 Descriptive statistics of SUS items related to the ARSLI

| Item                                         | N   | Mean | SD  |
|----------------------------------------------|-----|------|-----|
| Q1: I think that I would like to use the ARSLI frequently | 120 | 3.88 | 1.05 |
| Q2: I found the ARSLI unnecessarily complex   | 120 | 1.85 | 0.76 |
| Q3: I thought the ARSLI was easy to use       | 120 | 4.19 | 0.92 |
| Q4: I think that I would need the support of a technical person to be able to use the ARSLI | 120 | 1.79 | 0.69 |
| Q5: I found the various functions in the ARSLI were well integrated | 120 | 3.98 | 1.16 |
| Q6: I thought there was too much inconsistency in the ARSLI | 120 | 2.01 | 0.88 |
| Q7: I would imagine that most people would learn to use the ARSLI very quickly | 120 | 4.22 | 1.21 |
| Q8: I found the ARSLI very cumbersome to use  | 120 | 1.77 | 0.72 |
| Q9: I felt very confident using the ARSLI     | 120 | 4.58 | 0.70 |
| Q10: I needed to learn a lot of things before I could get going with the ARSLI       | 120 | 1.69 | 0.51 |

Fig. 5 Position of system usability scores for ARSLI

(Bangor et al., 2008; Brooks, 2013)
It is worth noting that the difference in students’ class levels had a significant influence on SV and the ATU. The mean of the lower-level students for these two constructs was higher than that of the more advanced students, demonstrating that lower-level students had a greater acceptance of stereoscopic AR images and positive ATUs. This phenomenon may be caused by advanced students having more knowledge of product design and being familiar with the styling objects. Therefore, the novelty of the topic is not as high as that for beginners. Lower-level students, however, were still learning product design. Therefore, they may have had a high level of interest in new design knowledge, giving them a higher learning identity and ATU. According to the questionnaire results, regardless of class level, participants had a positive attitude toward applying this AR technology to their course.

The LC mainly directly affected DI. According to student feedback, students believed the learning materials could include more product styling objects in distance learning. Moreover, they believed that these objects could improve learnability with higher interactivity, such as in the adjustment of product colors and the assembly of product parts. Students also considered the usability of interaction related to LC. This tendency was also noted in the path effects of TAM. Therefore, Hypotheses 4 and 5 are supported. This result demonstrates that DI can predict PU and the PEU.

DI did not directly affect the ATU (Hypothesis 10 was not supported), and the PEU was a vital mediator (Hypotheses 5 and 8 were supported). The ATU referred to a user’s overall evaluation of the system and involved positive and negative feelings. Additionally, the ATU affected the final BIU [1, 21]. This result indicated that the ARSLI must have satisfactory PEU before students can positively evaluate the entire distance learning interface. This result was consistent with the students’ experiential learning process. Students must first believe that the learning tool is easy to use before they can consider that the learning interface or system is useful and promotes positive ATU. The results of the SUS also demonstrated that this ARSLI had satisfactory usability, and students could easily use this learning interface. Most students indicated that operating the 3D objects or related functions through touch gestures was intuitive. They had positive evaluations and attitudes toward this learning interface.

PU referred to the students’ belief that using the system could improve their work performance [21]. In the path effects of this research model, the prediction of PU mainly comes from the DI factor (Hypothesis 4 is supported). Additionally, PEU did not directly affect PU (Hypothesis 6 is not supported). Hypothesis 7 was not supported, however, PU did not directly affect ATUs. This result demonstrated that the main factors affecting ATU depended on PEU rather than PU. PEU indicates that the user recognizes that the learning interface is easy to use and understandable. When a system or device is easy to use, users will have more self-efficacy and control than if it is difficult to use [21]. Some studies have also indicated that suitable ease of use improves the usability of a learning interface and the learning efficiency of users, especially for human–computer interaction interfaces for digital learning [24, 33].

Hypothesis 12 was also supported, demonstrating that attitudes could be used to predict behavioral intentions. The students’ positive attitude toward the ARSLI increased the probability of them using this learning interface. Overall, a progressive effect path was noted in the TAM of this learning interface. Some crucial influencing variables exist in the path from the front-end external variables to the last-end behavioral intention variable. During the learning process, students progressively experienced the interactivity and ease of use of the distance learning interface, which then influenced their ATU; then, they formed the formed BIU (or not use) the interface. The 3D SV of AR considerably affected students’ attitudes. Kaur et al. [40] emphasized that the visualization of an abstract concept could improve students’ motivation to learn. According to the observation of the students’ behavior toward this ARSLI, the students could use AR technology and maintain a positive learning attitude. In this study, students’ behavioral intentions and attitudes toward learning goals in this ARSLI were effectively explored using TAM. However, different levels of prior knowledge or learning backgrounds may produce different learning attitudes, related research topics can be explored in a TAM context in future work.

According to the results of the SUS, most participants were willing to use ARSLI frequently, and they were confident that they could use it. Although the participants’ acceptance of this learning interface was high, some usability matters, such as the stability of 3D objects and the interactivity of LC, required more attention. Participants emphasized that they found the inclusion of AR technology in distance learning interesting, particularly for styling design. Compared with the graphic teaching materials in traditional distance videos, many features and details of product styling could be observed through AR-aided distance learning interfaces. Participants also paid attention to the interactions of the distance learning community. Participants hoped to engage in more peer communication and design activities in the ARSLI, and most of the participants agreed that AR-aided distance learning could enhance the quality of their design learning experience.

The goal of the product styling course was to cultivate students’ observations and aesthetic internalizations of styling characteristics. However, because of the effect caused by
COVID-19 on education, students usually could not understand the semantics of styling that were conveyed by the teacher through traditional distance video learning. Therefore, students were prone to form gaps in design styling recognition and become frustrated. Through the ARSLI, the AR 3D styling visualization not only increased students’ motivation to learn but also provided students with an effective means of enhancing their recognition of design styling. The students’ negative emotions could be actively reduced in the process of styling design learning. Participants indicated that many product styling details and 360° viewing angles could be observed through the ARSLI. Students could quickly comprehend the concept and style of a product’s appearance. Furthermore, they believed that the efficiency of styling design learning improved through this learning interface and that learning became more interesting. Enhancing DI and 3D SV were the main learning features in the AR-aided styling learning process. ARSLI overcame the limitations of flat images of traditional teaching materials and is compatible with digital and traditional text learning styles. Additional content can also be designed for the AR interface. In the ARSLI DI process, the scanned content (object) is deemed part of the learning materials. Many participants also indicated that the layout design of the scanned content affected their intention to use ARSLI.

Some studies have indicated that a possible risk of cognitive load is associated with AR use [12, 35]. However, against the backdrop of the COVID-19 pandemic and in accordance with the characteristics of styling learning, flat information alone is insufficient for conveying the knowledge points of styling learning in a distance learning environment. According to students’ feedback on this ARSLI, the styling learning content transmitted through AR experiences was easy to understand. The students responded that they had greater access to learning information than with traditional textbooks. Similarly, Altmeyer et al. [2] indicated that the AR condition of learning provided substantial learning gains. In addition, smartphone devices have been regarded by many students as a daily necessity, and they can be easily used for distance learning. Therefore, AR was not considered to induce an additional cognitive burden; rather, it was perceived as a favorable alternative approach for distance learning.

The abstract product styling vocabulary could be conveyed concretely through 3D visualization in ARSLI, which could reduce the knowledge gap between teachers and students. The AR-aided distance learning modality, in which the learning experience and interface were improved, is presented in Fig. 6. AR technology effectively enhanced aspects of students’ learning experiences, including learning motivation, visualization, styling knowledge, and communication. ARSLI also improved students’ acceptance of distance learning and interactivity, usability, and flexibility during such learning. Students were willing to actively try this learning interface and offer effective learning responses. Students reflected on the benefits of this experience for styling learning and formed behavioral intentions. Therefore, students could have various learning experiences through diversified learning modalities during the COVID-19 pandemic.

6 Conclusion

To stop the spread of COVID-19, students and teachers were required to maintain a physical distance from each other. Therefore, distance learning became the main learning communication channel during the pandemic. However, the monotony and insufficient learning experiences of existing distance video learning were often criticized. The pandemic prompted the innovative development of learning environments. In this study, the distance learning experience of students in a product styling design course was enhanced through AR technology. Students experienced realistic objects that closely resembled actual products. Additionally, the 3D images presented in AR improved students’ thinking and memory skills. Compared with the teacher’s oral descriptions or static images displays, 3D visualization images aroused students’ interest in learning more, and they constructed the concepts of styling design elements more easily. Furthermore, the student-centered design of the ARSLI concretized the LC of product styling, which further increased students’ interactivity and usability. Smartphones and tablets are easy-to-use AR technology-assisted learning tools. ARSLI is a feasible, low-cost solution for distance learning, especially during the COVID-19 pandemic. In the
future, this learning mode may be applied to other design courses, and the development of a collaborative learning framework to improve the efficacy of the distance learning experience may be considered.

Acknowledgements This study was partially supported by the Ministry of Education, Taiwan, ROC under Grant No. PHA1100665.

References

1. Agarwal, R., Prasad, J.: A conceptual and operational definition of personal innovativeness in the domain of information technology. Inf. Syst. Res. 9, 204–224 (1998)
2. Altmeyer, K., Kapp, S., Thees, M., Malone, S., Kuhn, J., Brünken, R.: Augmented reality to foster conceptual knowledge acquisition in STEM laboratory courses – theoretical derivations and empirical findings. Br. J. Educ. Technol. 51(3), 611–628 (2020)
3. Altawajiry, N., Ibrahim, A., Binsuwaidan, R., Alnajjar, L.I., Alsfouk, B.A., Almutairi, R.: Distance education during COVID-19 pandemic: a college of pharmacy experience. Risk Manag. Healthcare Policy 2021(14), 2099–2110 (2021)
4. Alzueta, E., Perrin, P., Baker, F.C., Caffarra, S., Ramos-Usuga, D., Yuksel, D., Arango-Lasprilla, J.C.: How the COVID-19 pandemic has changed our lives: a study of psychological correlates across 59 countries. J. Clin. Psychol. 77(3), 556–570 (2021)
5. Armstrong-Mensah, E., Ramsey-White, K., Yankey, B., Self-Brown, S.: COVID-19 and distance learning: effects on Georgia State University School of public health students. Front. Public Health 8, 576227 (2020). https://doi.org/10.3389/fpubh.2020.576227
6. Balog, A., Priebeanu, C.: The role of perceived enjoyment in the students’ acceptance of an augmented reality teaching platform: a structural equation modelling approach. Stud. Inf. Control 19(3), 319–330 (2010)
7. Bangor, A., Kortum, P.T., Miller, J.T.: Determining what individual SUS scores mean: adding an adjective rating scale. J. Usabil. Stud. 4, 114–123 (2009)
8. Bertrand, M., Bouchard, S.: Applying the technology acceptance model to VR with people who are favorable to its use. J. Cyber Ther. Rehabil. 1(2), 200–210 (2008)
9. Bouchlaghem, D., Shang, H., Whyte, J., Ganah, A.: Visualization in architecture, engineering and construction (AEC). Int. J. Automat. Constr. 14, 287–295 (2005)
10. Brooke, J. (1996). SUS: A quick and dirty usability scale. In: Jordan, P. W., Thomas, B. A. Weerdmeester and McClelland, I. L. (eds) Usability evaluation in industry, London: Taylor & Francis. pp. 189–194
11. Brooke, J.: SUS: a retrospective. J. Usabil. Stud. 8, 29–40 (2013)
12. Bujak, K.R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., Golubski, G.: A psychological perspective on augmented reality in the mathematics classroom. Comput. Educ. 68, 536–544 (2013)
13. Bursali, H., Yilmaz, R.M.: Effect of augmented reality applications on secondary school students’ reading comprehension and learning permanency. Comput. Hum. Behav. 95, 126–135 (2019)
14. Butnaru, G.I., Nită, V., Anichiti, A., Brînză, G.: The effectiveness of online education during Covid 19 pandemic—a comparative analysis between the perceptions of academic students and high school students from Romania. Sustainability 13(9), 5311 (2021). https://doi.org/10.3390/su13095311
15. Cai, S., Wang, X., Chiang, F.K.: A case study of augmented reality simulation system application in a chemistry course. Comput. Hum. Behav. 37, 31–40 (2014)
16. Caliskan, S., Suzek, S., Ozcan, D.: Determining student satisfaction in distance education courses. Proced. Comput. Sci. 120, 529–538 (2017)
17. Choi, S.H., Kim, M., Lee, J.Y.: Situation-dependent remote AR collaborations: image-based collaboration using a 3D perspective map and live video-based collaboration with a synchronized VR mode. Comput. Ind. 101, 51–66 (2018)
18. Contero, M., Camba, J.D., Salvador-Herranz, G. (2014). Desktop vs. mobile: a comparative study of augmented reality systems for engineering visualizations in education. In: Frontiers in education conference (FIE 2014)
19. Contreras, G.S., Cepa, C.B.M., Fernández, I.S., Escobar, J.C.: Higher education in the face of the push of new technologies. Virtual, augmented and mixed reality in the teaching environment. Cont. Eng. Sci. 13(1), 247–261 (2020)
20. Daniel, S.J.: Education and the COVID-19 pandemic. Prospects 49, 91–96 (2020)
21. Davis, F.D., Bagozzi, R., Warshaw, P.R.: User acceptance of computer technology: a comparison of two theoretical models. Manage. Sci. 35, 982–1003 (1989)
22. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q. 13(3), 319–340 (1989)
23. Davis, F.D., Venkatesh, V.: A theoretical extension of the technology acceptance model: four longitudinal field studies. Inf. Syst. Res. 46(2), 186–204 (2000)
24. Devy, N. P. I. R., Wibramas S., Santosa, P. I. (2017). Evaluating user experience of English learning interface using user experience questionnaire and system usability scale. In: International conference on informatics and computational sciences, pp. 101–106
25. Dhawan, S.: Online learning: a panacea in the time of COVID-19 crisis. J. Edu. Technol. Syst. 49(1), 5–22 (2020)
26. Dix, A., Finlay, J., Abowd, G.D., Beale, R.: Human–computer interaction. Pearson Prentice Hall, Upper Saddle River, NJ (2004)
27. Dixit, R.V., Prakash, G.: Intentions to use social networking sites (SNS) using technology acceptance model (TAM): an empirical study. Paradigm 22(1), 65–79 (2018)
28. DK., Inc. (2015). Design: the definitive visual history, London: Dorling Kindersley Publishing
29. Eldokhny, A.A., Dowish, A.M.: Effectiveness of augmented reality in online distance learning at the time of the COVID-19 pandemic. Int. J. Emerg. Technol. Learn. 16(9), 198–218 (2021)
30. Elfridoussi, S., Lachgar, M., Kabahli, H., Roched A., Goudjami D., Firdoussi L. (2020). Assessing distance learning in higher education during the COVID-19 pandemic. Edu. Res. Int., 8890633
31. Fishbein, M., Ajzen, I.: Belief, attitude, intention, and behavior. Addison Wesley, Reading, MA (1975)
32. Garzón, J., Acevedo, J.: Meta-analysis of the impact of augmented reality on students’ learning gains. Educ. Res. Rev. 27, 244–260 (2019). https://doi.org/10.1016/j.edurev.2019.04.001
33. Granić, A.: Experience with usability evaluation of e-learning systems. Univ. Access Inf. Soc. 7, 209 (2008)
34. Guan, D., Wang, D., Hallegatte, S., et al.: Global supply-chain effects of COVID-19 control measures. Nat. Hum. Behav. 4, 577–587 (2020)
35. Ibili, E.: Effect of augmented reality environments on cognitive load: pedagogical effect, instructional design, motivation and interaction interfaces. Int. J. Progress. Educ. 15(5), 42–57 (2019)
36. Ibili, E., Resynsanky, D., Billinghurst, M.: Applying the technology acceptance model to understand maths teachers’ perceptions towards an augmented reality tutoring system. Educ. Inf. Technol. 24, 2653–2675 (2019)
37. Ibrahim, R., Leng, N.S., Yusoff, R.C.M., Samy, G.N., Masrom, S., Rizman, Z.I.: E-learning acceptance based on technology acceptance model (TAM). J. Fundam. Appl. Sci. 9(4S), 871–889 (2017)
38. Iftene, A., Trandabă, D.: Enhancing the attractiveness of learning through augmented reality. Proced. Comput. Sci. 126, 166–175 (2018)
39. Jackson, C.M., Chow, S., Leitch, R.A.: Toward an understanding of the behavioral intention to use an information system. Decis. Sci. 28(2), 357–389 (1997)
40. Kaur, D.P., Mantri, A., Horan, B.: Enhancing student motivation with use of augmented reality for interactive learning in engineering education. Proced. Comput. Sci. 172, 881–885 (2020)
41. Kentnor, H.: Distance education and the evolution of online learning in the United States. Curric. Teach. Dialog. 17, 15–41 (2015)
42. Kim, H.C., Hyun, M.Y.: Predicting the use of smartphone-based augmented reality (AR): Does telepresence really help? Comput. Hum. Behav. 59, 28–38 (2016)
43. Kim, K., Hwang, J., Zo, H., Lee, H.: Understanding users’ continuance intention toward smartphone augmented reality applications. Inf. Dev. 32(2), 161–174 (2016)
44. Legris, P., Ingham, J., Collerette, P.: Why do people use information technology? A critical review of the technology acceptance model. Inf. Manage. 40(3), 191–204 (2003)
45. Loukatos, D., Zoulas, E., Kyrtopoulos, L.V., Chondrogiannis, E., Arvanitis, K.G. (2021). A mixed reality approach enriching the agricultural engineering education paradigm, against the COVID-19 constraints. In: IEEE global engineering education conference, EDUCON 2021, pp. 1587-1592
46. Lucas, H.C., Spitler, V.K.: Technology use and performance: a field study of broker workstations. Decis. Sci. 30(2), 291–311 (1999)
47. Manis, K.T., Choi, D.: The virtual reality hardware acceptance model (VR-HAM): extending and individuating the technology acceptance model (TAM) for virtual reality hardware. J. Bus. Res. 100, 503–513 (2019)
48. Navimipour, N.J., Zareie, B.: Technology use and performance: a field study of broker workstations. Decis. Sci. 30(2), 291–311 (1999)
49. Omwansa, K., Waema, T.M.: Application of technology acceptance model (TAM) in M-banking adoption in Kenya. Int. J. Comput. ICT Res. 5(1), 31–43 (2012)
50. Parka, C.W., Kim, D.K., Cho, S., Han, H.J.: Adoption of multimedia technology for learning and gender difference. Comput. Educ. 92, 288–296 (2019)
51. Purwanto, A., Asbari, M., Fahlevi, M., Mufid, A., Agiสถาวัติ, E., Cahyono, Y., Suryani, P.: Impact of work from home (WFH) on Indonesian teachers performance during the Covid-19 pandemic: an exploratory study. Int. J. Adv. Sci. Technol. 29(5), 6235–6244 (2020)
52. Rizaldi, D.R., Fatimah, Z.: How the distance learning can be a solution during the Covid-19 pandemic. Int. J. Asian Edu. 1(3), 117–124 (2020)
53. Sahin, D., Yilmaz, R.M.: The effect of augmented reality technology on middle school students’ achievements and attitudes towards science education. Comput. Edu. 144, 103710 (2020)
54. Serio, Á.D., Ibáñez, M.B., Kloos, C.D.: Impact of an augmented reality system on students’ motivation for a visual art course. Comput. Educ. 68, 586–596 (2013)
55. Shneiderman, B., Plaisant, C.: Designing the user interface. Addison-Wesley, Boston, MA (2004)
56. Simonson, G.A.B.: Distance learning education. Encyclopedia Britannica Inc, Britannica (2016)
57. Sindiani, A.M., Obeidat, N., Alshaiaf, E., Elsalem, L., Alwani, M.M., Rawashdeh, H., Fares, A.S., Alalawne, T., Tawalbeh, L.I.: Distance education during the COVID-19 outbreak: a cross-sectional study among medical students in North of Jordan. Ann. Med. Surg. 59, 186–194 (2020)
58. Stone, D., Jarrett, C., Woodroffe, M., Minocha, S.: User interface design and evaluation. Morgan Kaufmann, San Francisco, CA (2005)
59. Sumadio, D. D., Dwistratanti, Rambl, D. R. A. (2010). Preliminary evaluation on user acceptance of the augmented reality use for education. In: The second international conference on computer engineering and applications, pp. 461–465
60. Sung, E.: The effects of augmented reality mobile app advertising: viral marketing via shared social experience. J. Bus. Res. 122, 75–87 (2021)
61. Vagg, T., Balta, J.Y., Bolger, A., Lone, M.: Multimedia in education: What do the students think. Health Prof Edu 6(3), 325–333 (2020)
62. Venkatesh, V., Davis, F.D.: A theoretical extension of the technology acceptance model: four longitudinal field studies. Manage. Sci. 46(2), 186–204 (2000)
63. Watson, A., Lupton, D., Michael, M.: Enacting intimacy and sociability at a distance in the COVID-19 crisis: the sociomaterialities of home-based communication technologies. Med Int Aust 178(1), 136–150 (2021)
64. Wei, X., Weng, D., Liu, Y., Wang, Y.: Teaching based on augmented reality for a technical creative design course. Comput. Educ. 81, 221–234 (2015)
65. Zorzal, E.R., Gomes, J.M.C., Sousa, M., Belchior, P., da Silva, P.G., Figueiredo, N., Jorge, J.: Laparoscopy with augmented reality for a technical creative design course. Comput. Educ. 144, 103710 (2020)
66. Zorzal, E.R., Gomes, J.M.C., Sousa, M., Belchior, P., da Silva, P.G., Figueiredo, N., Jorge, J.: Laparoscopy with augmented reality for a technical creative design course. Comput. Educ. 144, 103710 (2020)

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor holds exclusive rights to this article under applicable law. Springer Nature or its licensor holds exclusive rights to this article under the terms of such publishing agreement and applicable law.