Enhancing Student Learning of Multimedia Design Concepts Using Augmented Reality

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Abstract. The rapid inclusion of digital and immersive technologies in education is fast evolving the learning and teaching processes, leading to the evolution of enhanced learning environments, with the purpose of bridging the gap between the evolving students' living styles and the passive learning classrooms. This study seeks to enhance the students' learning of multimedia design concepts using Augmented Reality (AR) as an instructional tool with Kolb's Experiential Learning Model (ELM) as the underlying theory. 30 postgraduate students from Multimedia University, Malaysia, were chosen as the sample for this study and a mixed mode research methodology was undertaken for the data collection. An AR app simulator was developed and mapped to the learning of Design Principles using 4 elements of ELM. Other than the students being exposed to the learning from AR app, the data was collected through MCQ based Pre-Post tests, a survey questionnaire and open ended questions. While statistically significant improvements in students' learning was reported from the test results, the comments and feedback also showed strong support towards increased interest in learning and raised levels of motivation, engagement & interaction. The data analysis & results provide strong indication for inclusion of immersive technologies, such as AR, for enhanced learning processes, guided by ARELE (Augmented Reality supported Enhanced Learning Environment), a learning framework to help the practitioners & educators construct a holistic, engaging, immersive and interactive learning environment.

Keywords: E-Learning · Augmented Reality · Constructivism · Experiential Learning · Design Principles

1 Introduction

Education has always been an area of deep interest for the researchers and the academicians. In this 21st century, this sector is undergoing immense research & upgradation, so as to fill in the growing gap between the student's tech savvy living-learning styles and the passive teaching methodologies undertaken in the learning institutions [1], leading to reduced interest and engagement of the learners in the classrooms, and thereby raising the need to add modern day technologies to improve the delivery, impact and retention of the educational material [2], and creating a holistic, meaningful and constructive teaching and learning environments, where not just the teachers but also students understand

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the importance and requirement of the quality education and feel motivated towards the classroom learning [5].

For building such constructive learning environments, the focus on the inclusion of online, web and immersive technologies in education is fast gaining momentum. As per the Education Horizon Reports of 2020 and 2019 [1], technologies, such as Mixed Reality, Virtual Reality (VR) and Augmented Reality (AR), are bringing a revolution in the education sector due to their positive and engaging impact on the interactivity between the user, the real world and the virtual space in the context of learning [4].

AR provides an enriched learning environment [6] by overlaying rich media (3D, 2D & online content) virtually over the real world objects, but it's more sophisticated usage and inclusion in education needs to be explored [2]. There is still a requirement for proper instructions/guidelines for the inclusion of this technology in the classroom structure [7] so as to render a visually rich understanding of the real world complex concepts by the students.

While the use of AR for an enhanced learning experience has been indicated in the arenas of STEM, Business, Law, History & Geography, to name a few [5], its inclusion in the study of basics of design & multimedia, especially design principles, is very limited. Therefore, this research study aims to investigate the students' perceptions of studying design basics using AR and thereby providing a framework for an enhanced classroom learning experience using immersive technologies, like AR. Davis Kolb's (1984) 4 elements of Experiential Learning Model (ELM) were undertaken as the theoretical base for developing the AR app modules and to subsequently answer the research question, *"How does AR as an instructional tool enhance the student learning and understanding of design principles?"*.

1.1 AR in Education

Augmented Reality (AR) has been designated as an immersive technology supporting an interesting amalgamation of real and virtual (2D & 3D) objects [4] and rendering an enhanced and an interactive experience [9]. In education, its incorporation from the teaching perspective has been noticed in the form of (1) course delivery and (2) providing supplemented information over the presented learning material [5]. The best examples [4] of the use of AR in education have been virtual viewing of - solar systems; human biology; photosynthesis process; architecture styles; etc. Its incorporation into the curriculum has highlighted its promising nature in terms of enhanced and interactive classrooms [9], leading to an increased student motivation & interest [12], involving direct interaction of the learners with the study material. Besides these, long term memory retention, better investigation skills [6], reduced cognitive load, in depth understanding of spatial structures [13], positive attitude, increased content understanding and concentration [5] are some of the other positive aspects of AR.

Though many benefits of AR have been recorded, its full potential still needs to be harnessed in education [2]. Many instances of its inclusion for the teaching and learning of subjects such as Physics, Chemistry, Biology, Aeronautics, History and Architecture have been recorded, with Science leading the charts with 40% research [14]. Other subjects such as Mathematics, Architecture, History & Geography, Law, Business and

Social Sciences follow closely [5], thus imparting 3D visuals and explanations of complex problems and concepts through computer simulations. Although Humanities & Arts have close to 21.9% of AR research experiments, only specific aspects of it such as visual arts, multiculturalism, language learning and painting appreciation have the documented evidence of AR based learning [5]. The basic concepts of design & multimedia, such as design elements and principles which requires the learners to have a visually rich learning and understanding related to their application in real world environment, lacks sufficient integration of AR towards studying them, thus leading to lack of interest, motivation and in depth understanding among the design students due to the passive way of teaching and learning, thereby raising the need for an enhanced learning environment giving them an immersive, in-depth and a good visualization based, learning experience.

1.2 Theoretical Underpinning

To overcome the growing gap between teaching and learning due to advancement in technologies and make the learning environment more exciting, inviting, motivating and engaging for the learners, the implementation of AR in the curriculum requires a proper structure or framework that is built on a substantial theoretical foundation. Thus, a proper inclusion of digital technology is required for which the researcher of this study had developed an AR learning app simulator using David Kolb's Experiential Learning Model (ELM) (1984). This model defines 4 stages of knowledge construction through transformation of experience such as:

- Concrete Experience (CE) - in depth involvement of the learners in the learning environment giving them an enriched experience
- Reflective Observation (RO) - allowing learners to reflect back and observe their experiences from different perspectives
- Abstract Conceptualization (AC) - learners integrating their observations into logically sound concepts and theories
- Active Experimentation (AE) - learners using the above created theories to solve complex problems

Experiential Learning is a self-directed, learning by doing process, wherein the learner understands and cultivates his own process of learning [3]. Identifying the problems, reflecting and making decisions, applying solutions and then testing those solutions is what makes it an experience based lifelong learning cycle [10]. This theory shifts the classroom learning from teacher centred to student centred, with teacher's role being that of a facilitator/guide. Based on this concept, David Kolb's Experiential Learning Model (ELM) has found its application in the construction of various modern day learning environments as it supports experience based learning that is authentic and immersive [8], thus leading to lifelong retention of learning concepts with an increase in learner interests, motivation, engagement, self-confidence, critical thinking and problem solving [11]. Keeping these benefits in view, the ELM elements were chosen as the theoretical base for constructing an enhanced classroom learning environment while an AR app simulator was chosen for its effective implementation.

Table 1. Mapping of ELM elements to the class environment

Experiential Learning Elements *(Kolb, 1984)*	**Enhanced Classroom Learning Activities**
Concrete Experience	Students given a basic understanding on the importance and use of design concepts in real world Authentic, real time experience of the concepts given to the students by way of augmented 3D exploration Use of embedded rich media and web 2.0 tools to provide extra information to the students leading to in depth knowledge Use of a Guided Learning experience for easy, smooth and meaningful learning process
Reflective Observation	Students made to deepen their knowledge by going through real world examples of application of design concepts Students made to reflect back on their understanding of concepts through formative assessments
Abstract Conceptualization	Lecturer, who is now the facilitator, evaluates the students based on their performance Students are given constructive feedback, guidance and perspectives on the concepts they lack so as to reevaluate their understanding and form concrete ideas
Active Experimentation	Students made to test their formed ideas and understanding through execution of their individual projects/assignments, leading to another cycle of concrete experience and reflection

2 Methodology

For constructing an enhanced student learning environment, David Kolb's 4 Experiential Learning elements were mapped to the design class (as seen in Table 1).

This was followed by its implementation using an AR app simulator (as seen in Fig. 1) to study the basics of design i.e. design principles, such as Balance, Harmony, Perspective, etc.

To illustrate the visual appeal of the content in the app, Figs. 1, 2, 3 and 4 show the images in the AR app that correspond to Kolb's 4 ELM elements.

The mapping of ELM model's 4 elements to the in-class implementation has been explained in Fig. 4.

To study the impact of AR supported enhanced learning, a mixed mode research methodology, including both quantitative and qualitative data collection instruments, was undertaken for the sample population i.e. 30 students of Multimedia University, Malaysia. While the qualitative data instruments involved the collection of student responses to few open ended questions, the quantitative instruments included a pre-test, a post-test and a survey questionnaire that were administered to them at different phases

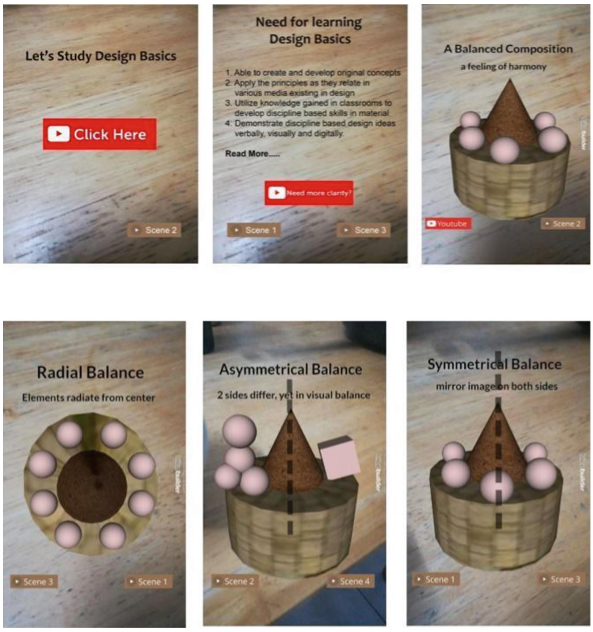

Fig. 1. Interfaces of the AR app that correspond to ELM Model's Concrete Experience

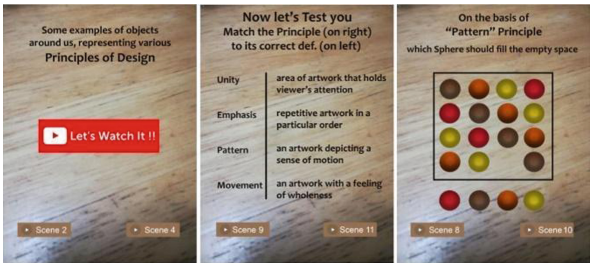

Fig. 2. Interfaces of the AR app that correspond to ELM Model's Reflective Observation

of the research study. The demographic information pertaining to the respondents' age and their prior use of AR technology was also collected and taken into consideration.

3 Analysis and Results

The demographic data collected reported 27 students between the age of 24–34 years, 2 above 34 years and 1 less than 24 years. The data also indicated that 25 out of 30 students (83%) had only experienced AR through games and QR codes while remaining 5 students (17%) didn't use AR in any form prior to this research study. After demographic data a pre-test, wherein the students' current understanding of the design principles such as Proportion, Contrast, Harmony, Balance, etc., were tested through a 20 MCQ questionnaire, followed by their exposure to an enhanced and immersive learning experience

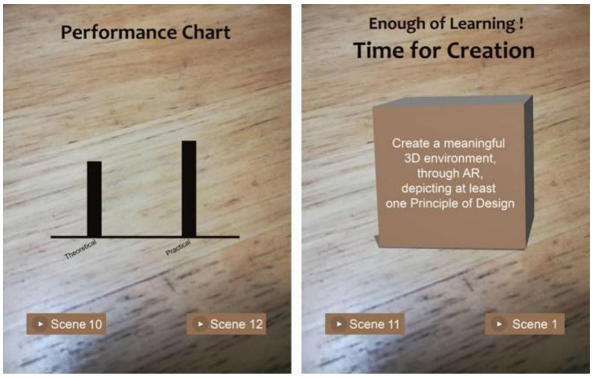

Fig. 3. Interfaces of the AR app that correspond to ELM Model's Abstract Conceptualization & Active Experimentation

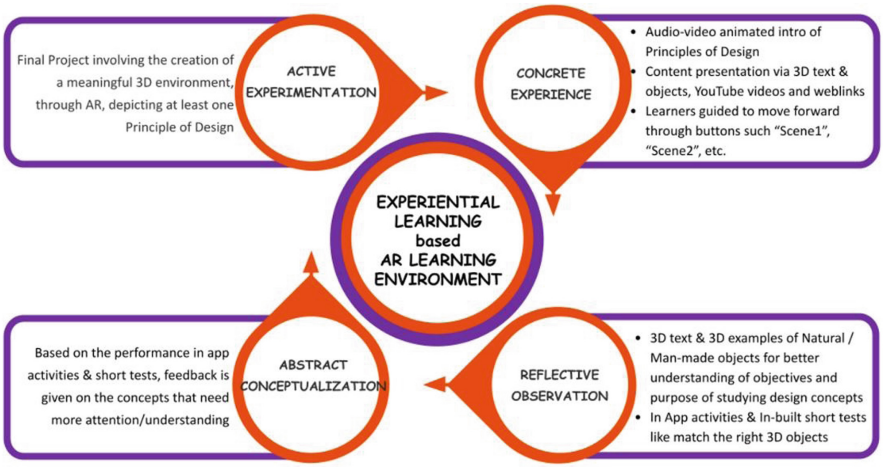

Fig. 4. Implementation of ELM based class activities in AR app Simulator

of these principles through an AR simulator app (Blippar), which exhibited the content in a real life setting and was underpinned by Kolb's (1984) 4 elements of Experiential Learning Model (ELM). After the participants were given ample time to experience the learning through the AR application, they were given a post-test (copy of pre-test questionnaire) to gauge their post understanding of the topic. The scores of both the pre- and post-tests were analysed using SPSS, including the means & standard deviations (refer to Table 2).

Table 2. Paired Sample Statistics

N = 30		**Mean (M)**	**Std. Deviation (SD)**
Pair 1	Pre-test Score	9.13	3.441
	Post-test Score	12.33	3.565

Table 3. Paired Sample Statistics

						t	**df**	**Sig. (2-tailed)**
	Mean	**Std Dev**	**Std Error Mean**	**95% Confidence Interval of the Difference**				
				Lower	Upper			
Post test - Pre test	3.200	.71438	.1304	2.933	3.467	24.5	29	< .001

A post-test mean score of 12.33 compared to pre-test mean score of 9.13 showed a significant improvement in the learning of the content. This was followed by calculating the paired sample T-Test to add more value to the mean score difference (refer to Table 3). The results ($t = 24.535$), with $p < 0.001$, were statistically significant, indicating a positive correlation between the exposure of the students to an enhanced learning environment using AR app simulator and the increase in the amount of understanding of the content through this AR based immersive experience, which is in line with research by [12] and [14].

Besides the above tests, some data regarding the students' perception about the AR supported learning process was collected through some open ended questions and a survey questionnaire, based on 5-point Likert Scale ranging from, 5 = Strongly Agree; 4 = Agree; 3 = Undecided; 2 = Disagree, and 1 = Strongly Disagree. The areas that were looked into, and which find support in literature as well, are: Interest/Appeal [1, 15]; Increased/Well-supported Learning [6, 12, 14]; Motivation [5, 13, 16] and Interaction & Engagement [4, 7] and [9]. Each of these constructs had 5 statements to gauge the participant's perception.

Table 4. Survey results on the Interest/Appeal construct

Interest/Appeal			
Item	**Mean (M)**	**Std. Dev (SD)**	**% (p)**
1.The use of AR for the study of Design Principles was quite interesting	3.73	.828	76.7
2. My interest level increased with the combination of 3D visualizations of concepts and 2D info materials.	3.73	.640	76.6
3. It gave me great ideas of using this combination for designing my projects and learning other topics as well.	3.40	1.037	60.0
4. The inclusion of various other info links such as YouTube, e-books & references further maintained my interest.	4.07	.450	93.3
5. AR technology seems to be very appealing for the study of various kinds of subjects.	4.10	.759	90.0
Student Comments *1. "It is such an exciting and easy to use technology".* *2. Would like to see its application in other subjects as well."* *3. "I think I understand the design principles much better now. The supplementary information available through YouTube videos was very helpful."* *4. "Increased my understanding of design principles so I can now easily apply them in my projects"*			

Starting with the Interest/Appeal construct (refer to Table 3), 90% and 76.7% of the students felt that studying through AR technology was quite appealing (Item no = 5; Mean = 4.10) and interesting (Item no = 1; Mean = 3.73), respectively. 93.3% felt that the YouTube video links and e-books maintained their interest (Item no = 4; Mean = 4.07) and 76.6% (Item no = 2; Mean = 3.73) of students showed excitement and positive support for studying through the combination of 3D visuals and 2D information materials. These numbers are strongly supported by various student comments as seen in Table 4. The overall results of this construct indicate AR as an interesting medium for student learning, as suggested by [4] and [15] in their research.

Next the students' experience in terms of increased and well supported learning (refer to Table 4) was asked for, upon which 90% of them felt that AR supports the learning process well (Item no = 5; Mean = 4.07). The other statements, like better understanding of the concepts due to 3D examples and activities (Item no = 1; Mean = 3.93); able to relate the 3D & 2D explanations to the surrounding objects (Item no = 3; Mean = 3.63); learning was easy and in-depth (Item no = 2; Mean = 3.63) and the enhanced learning due to additional resources (Item no = 4; Mean = 3.97), also saw good support by 86.3%; 66.6%; 70% and 76.7% respectively. The above numbers are supported by student comments as seen in Table 5. These results strongly encourage the use of AR for an enhanced and well supported learning process as reported by [6, 12] and [14] in their research.

Table 5. Survey results on the Increased/Well Supported Learning construct

Increased/Well Supported Learning			
Item	**Mean (M)**	**Std. Dev (SD)**	**% (p)**
1. The AR App made me understand the concepts more clearly due to its 3D realistic setting	3.93	.868	86.3
2.The learning of design basics has never been so easy and in-depth	3.63	.928	70.0
3. I can now relate the understanding of the Design Principles to my surrounding objects	3.63	.928	66.6
4. Besides 3D, other types of information sources available to supplement the explanation, lead to an increased learning	3.97	.999	76.7
5. AR is a great tool/technology to support the learning process.	4.07	.640	90.0
Student Comments *1. "It helped me understand the principles much better and in an interactive way."* *2. "The information given was in a creative, fun, interesting way. It helped me clear out most of the questions I had about certain parts of the topic."* *3. "It helped me by providing summarized, concise, and useful information in an engaging manner where I would also be able to do quiz/game to help me with self-evaluation, and ultimately help me with my studying and explaining to others."*			

Motivation was the next construct that was looked into (refer to Table 6), in which 90% of the students were positive about studying the design concepts using an immersive technology (Item no = 1; Mean = 4.17), and having more AR based learnings in other subjects (Item no = 5; Mean = 4.17). Meanwhile, 86.7% of them felt enthusiastic about using AR to understand in 3D/realistic versions and apply the concepts in real surroundings (Item no = 4; Mean = 4.0) and 80% of them felt highly motivated (Item no = 2; Mean = 3.83). To further support these numbers, student comments can be seen in Table 6. Overall, the results indicate high motivation among students to study and learn their concepts using AR, which supports the research by [5, 13] and [16].

Interaction & Engagement was the last construct that was taken into consideration (refer to Table 6). While 96.7% of the students supported an increase in self-confidence and self-esteem (Item no = 5; Mean = 4.20), 83.3% of them were positive about the versatility of the AR app in helping them to share their knowledge and experiences (Item no = 3; Mean = 4.0) and 73.3% of them found it helpful in interacting with other fellow students (Item no = 1; Mean = 3.77) and were eager to collaborate using this technology in other subjects (Item no = 4; Mean = 3.37). Student comments as seen in Table 7 further supports the above quantitative results. Overall the students were optimistic about the interaction and engagement along with increased self-confidence and self-esteem, which supports the findings of [9].

Table 6. Survey results on the Motivation construct

Motivation			
Item	**Mean (M)**	**Std. Dev (SD)**	**% (p)**
1. Studying of design basics through a reality immersive technology was a different yet exciting experience	4.17	.592	90.0
2. I feel motivated to study multimedia through AR	3.83	.791	80.0
3. I would like to have more of my course content delivered through AR tools	3.77	.898	76.7
4. This technology has given me enough enthusiasm to understand and apply these concepts in real world settings.	4.00	.643	86.7
5. I would like to induce AR in learning of my other subjects as well.	4.17	.791	90.0
Student Comments *1. "I really enjoyed learning the design topic through AR."* *2. "I am feeling positive and excited after learning the same topic in a different manner. Until now, I only visualized the design principles in my imagination in 3D perspective, but now I could see them as well."* *3. "A fun way to learn a topic."* *4. "Cool way to learn through AR app. Made me feel motivated to explore other subjects also through AR."*			

Table 7. Survey results on the Interaction & Engagement construct

Interaction & Engagement			
Item	**Mean (M)**	**Std. Dev (SD)**	**% (p)**
1. The use of AR for learning activities helped me interact with other fellow university students in understanding and discussing it	3.77	.935	73.3
2. Due to increased interaction, I was able to know many of the university mates and faculty students whom I never had a chance to talk to.	3.77	.935	73.3
3. It further helped me and others in sharing our knowledge and experiences.	4.00	.788	83.3
4. We are eager to collaborate in other subject learnings as well.	3.37	.999	60.0
5. I felt an increase in my self- confidence and self-esteem.	4.20	.484	96.7
Student Comments *1. "The ability to interact with it was something that I found interesting."* *2. "The app kept me engaged throughout my learning so I understood the topic well"* *3. "Easily can explain to my friends and I can find my answers quickly too"* *4. "The way this learning technique kept me engaged throughout my learning, I have understood quite a lot and can easily explain to others."*			

4 Discussion

The data collected showed a positive support towards the learning of design concepts, such as Principles of Design, through the inclusion of AR technology, underpinned by Kolb's (1984) ELM Model. The students' comments, reporting an exciting and interesting learning experience, enhancing their understanding and clarity of the concepts, strongly backs up the quantitative results. Therefore, in answering the research question, *"How does AR as an instructional tool enhance the student learning and understanding of design principles?"*, the results of the research study outlines several major outcomes that resulted from the enhanced learning environment due to the inclusion of AR. These outcomes are discussed as follows:

1. AR supported the learning process, with the inclusion of online information links, videos, and 3D explanations of real world objects and engaging activities, **maintained student interest and made it quite appealing,** thus supporting the benefits of AR in education by [15].
2. Learning through the use of an advanced and immersive technology with 3D explanations was perceived as an **increased, well supported and enhanced learning** by the students, which is also in conjunction with the research on AR by [6, 12] and [14].
3. **Motivation** was another important perceived outcome of the data analysis and student comments based on the realistic and immersive experience that they had in this learning process, which supports the research findings by [5] and [13].
4. A progressive increase has also been analysed in the form of **student interaction & Engagement**, as students were reported helping each other in solving complex activities and sharing their knowledge and understanding, leading to an usher of self-esteem and self confidence in them, which supports the research by [9].
5. The analysis and results also lend **a strong and positive support towards the use of Kolb's (1984) ELM Model**, as theoretical base, in constructing an enhanced learning environment with the inclusion of immersive technologies such as AR.

Therefore, based on the overall analysis, results & discussions from this study, a learning framework, the Augmented Reality supported Enhanced Learning Environment (ARELE) underpinned by Kolb's (1984) Experiential Learning Model (ELM), is proposed as a guideline for those practitioners and educators who are willing to take their classrooms to next level by incorporating immersive and reality focussed technologies such as Augmented Reality into their curriculum (refer to Fig. 5).

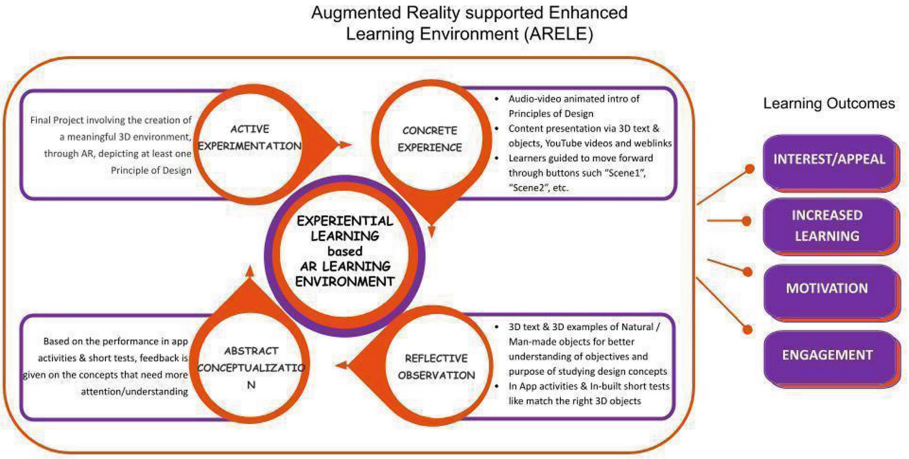

Fig. 5. The ARELE learning framework for including Augumemted Reality as an instructional tool in a learning process.

5 Conclusion

This research study started with an identified gap between students' current learning styles and the passive teaching methodologies due to the induction of vast amounts of technologies and digital devices in the day to day life of the learners, thus reducing their interest in regular classrooms and thereby raising the need for holistic, enhanced and engaging learning environments. Therefore to create such engaging learning spaces, this study sought to include immersive technologies such as AR into the classrooms with Kolb's 4 ELM elements as the theoretical base. Although the inclusion of AR has been documented in the education fields like STEM, Social Sciences, Architecture, etc., little evidence is available for its inclusion in the Multimedia field with respect to studying its concepts & basics, which require a deep understanding of the application of it in the real world settings. Keeping this in view, this research study aimed to answer the research question, *"How does AR as an instructional tool enhance the student learning and understanding of design principles?"* To answer this RQ, an AR simulator app for the learning of design basics was developed and 30 students as samples were made to use this app to study the concepts. The amount of learning was analysed through pre and post-tests and their opinion was recorded through questionnaires and open ended comments.

From the data analysis, results and discussions, the researcher concluded that the use of AR, as an addition to enhance the learning environment and help students learn the design basics, was quite effective, as the students expressed high motivation (connects with research by [5]), engagement & interaction (connects with research by [9]), interest levels (connects with research by [15]) and well supported learning (connects with research by [12]). The learning framework, ARELE, generated as an outcome of this study, can work as a strong guideline for research in other education fields with respect to using AR as an instructional tool for an enhanced learning environment.

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Authors' Contributions. NM conceived the research idea, studied the past literature, prepared the research design and the AR app simulator followed by carrying out research data collection and drafting the manuscript.

MN guided NM in the research design, giving a direction to the research and preparation of data collection instruments. MN also worked on the data analysis, finding and interpretation of results and discussions.

All authors approve the final manuscript.

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