Title:
Enhancing the pedagogic impact of Augmented Reality experiences: storyboarding as a human-centred design approach

Authors:
Omar Huerta-Cardoso, o.i.huertacardoso@leeds.ac.uk, University of Leeds, UK.
Ertu Unver, e.unver@hud.ac.uk, University of Huddersfield, UK.
Abdil Kuş, abdilkus@uludag.edu.tr, Uludag University, Turkey.
Ridvan Arslan, ridvan@uludag.edu.tr, Uludag University, Turkey

Keywords:
Human centred design, Storyboarding, Augmented reality, Pedagogy, Technical drawings

DOI: 10.14733/cadconfP.2023.350-356

Introduction:
Augmented Reality (AR) has come a long way from a science-fiction dream to a science-based reality. AR brings and enhanced view of the real, physical world with the help of computer-generated elements. These elements may range from sound to video, to graphics to GPS overlays and many more. The development of AR applications has evolved and now requires collaborative teamwork. AR has quickly found its way into commercial applications for different sectors such as advertising, education, healthcare, and entertainment, showing potential for engaging with new generations of users.

Higher education institutions have raised some concerns on the difficulty of teaching and learning abstract and complex topics (i.e., design and engineering). There is growing evidence that simulations/animations along with AR can improve learners' engagement, competence, and skills; especially when compared to traditional didactic methods. However, the overall teaching and learning experience happens within a complex system that dictates the requirements needed for an AR application to cover user expectations and in consequence to be fully embraced in such complex systems. The challenge is to develop new and appropriate T&L tools and methods that can be used in a complex system where lecturers, students and other stakeholders involved in the learning process need to meet the demands of both academia and industry.

This work will not address the limitations or effectiveness of AR in education; instead, it expands on the use of storyboarding to increase the pedagogical impact of AR in complex teaching systems, in particular for design and engineering topics. This work explores the use of this tool (storyboarding), to bring a practical and human-centred approach at early stages of the development and testing of AR applications, when little changes may have a larger impact down the line.

AR in education and the need for a balanced approach
The decline in technical skills and understanding of essential principles and the conventions that underpin complex and abstract topics (i.e., technical drawings) represent a challenge for HE institutions [35]. There are many traditional and more modern teaching and learning (T&L) approaches and methods. Some may consist of conventional lectures, tutorials, or laboratory-based sessions. Others incorporate real-life concepts, experiences, technologies [26],[33] and project-based work. However, these are usually isolated from each other [28]. Additionally, there are different learning styles that may be present in a cohort. Despite design students tend to have visual, inductive, and active learning styles; most engineering education and in particular the teaching of technical drawing skills has relied on auditory, abstract, deductive, passive, and sequential teaching styles [15]. These

days it is more common to find students with reduced attention levels throughout a whole lecture; even when active learning strategies are used to improve learning and attention spans [29]. Moreover, the traditional teaching methods are missing the adequate interaction between the academic staff and the students, especially when students are passive learners [28],[32], and when more recent teaching strategies based on cognitive sciences have shown how the knowledge can be constructed by the student [10],[11].

The overall effect of augmented reality-based methods and tools on the teaching and learning experience has been deemed positive [3]. AR applications have found their way into HE settings as they provide help on the delivery of abstract topics [24]. These abstract and complex topics have always been and will continue to be an essential component in the formative education of professionals.

The Students experience

AR has become popular and it is widely used in educational settings offering many advantages [7], it no longer requires expensive hardware or sophisticated equipment, the technology now can be used with computers or mobile devices, and it has been used already in every level of schooling, from K-12 to university level. [8],[13],[22]. AR helps students engage in explorations and increases motivation, but how are the elements that create this motivation being considered? This brings an important question into the development of AR applications; who is the user? what do they need? and how AR developments can consider these different needs?.

The Lecturers experience

Teaching has become a challenge. New pedagogical approaches in which the conventional notion of classroom-based learning is inverted, and the use of new technologies has open up the access to learning to a wider community. However, as it has been shown, some lecturers lack experience using new technologies such as VR, in some cases laboratories are not equipped to deal with VR, and textbooks and current teaching materials could not support the implementation of these new technologies. Recent research outcomes have tried to recommend teaching methodologies with the use of VR in engineering education; but there are still uncertainties over how to implement VR into engineering education [18]. Hence, new AR and VR developments with a focus in education should consider the T&L experience as a complex activity where lecturers are an important part of it with their particular needs and limitations.

The Context / scenario of use

Context or scenario are terms frequently used in the design field to make reference to the circumstances, background, or environment in which a user and product coexist through a series of interactions. Here, it is important to mention that sociocultural aspects are entwined with the environment where the interactions occur, therefore the context also refers to the immediate physical and social setting where the users, and in this case AR applications coexist. Consequently, the “context of use” can determine the purpose, design and function of an AR application. Furthermore, the consideration and understanding of a “context of use” should help ground the initial idea and make seemingly unclear problems more tangible. Also, having a clear understanding of the context(s) before any AR development start should help developing an application that fits into the real world, where it will be actually used with all the restrictions or problems it may represent for every type of user.

The quest for a balanced approach

AR has been perceived as a highly technological product. During the early years of AR, developments were done through a technology push strategy. Then it was more important to bring both physical and virtual worlds together rather than to consider thoroughly the why behind such cutting-edge developments. Nowadays, AR developments have been moving away from that notion towards a more user-centred approach that is both technology efficient and user friendly.

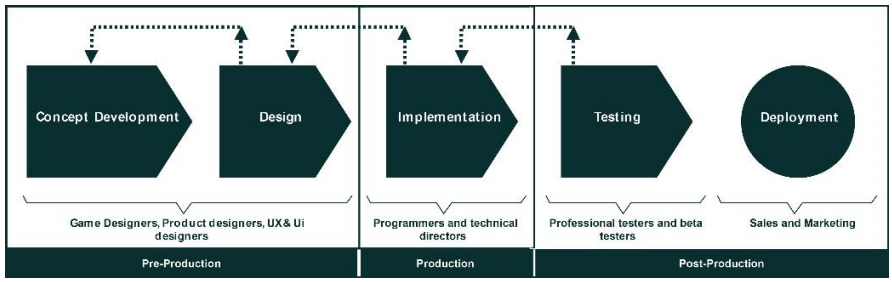

Fig. 1: AR development process.

The AR developments based on technology-driven approaches and interactive tools, have shown to incrementally improve the efficiency. However, not having the user at the core of the development somehow limits the application impact by losing sight from the people (i.e. student and lecturer) who is involved in the overall use of the application. Traditionally, many methodologies have been applied in the development of T&L materials, design of subjects, information technology, and AR applications (see Fig. 1).

T&L is a complex task, and technology driven developments may not foster student's learning [12] and some topics (e.g., technical drawings) require an interactive dialog and co-operation between lecturer and students to facilitate the construction of knowledge. This interaction may occur in a variety of media types, forms of interaction and contexts. Hence, a purely software-technology driven approach may not provide an opportunity to fully address the relevant needs for a successful teaching and learning experience [5],[12],[27]. Therefore, an integration of a human-centred approach that combines pedagogy and technology can provide better considerations for the addressing of learning difficulties to enhance the impact or AR applications in educative environments [6],[9] through a complete understanding of users' needs, and how their emotions drive their decision-making process [34].

The rationale behind a human-centred approach for the development of an AR-based application with pedagogic purposes, is the search for the right balance between the many teaching methods and learning styles, as well as the stakeholders involved in the T&L experience, and the context where this experience happens. In the quest of this balance, the teaching methods and relevant topics should be appropriately matched with the different learning styles and scenarios where the T&L occurs to deliver an enhanced learning experience (see Fig. 2).

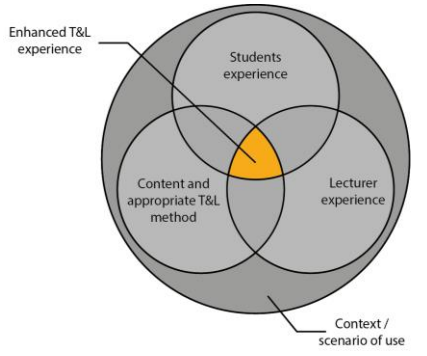

Fig. 2: Elements for a balanced and enhanced T&L experience.

Storyboarding (a storyboarding story):

The development of didactic materials based on AR applications through a "design" approach involves a sense of anticipation of the communication processes involved in the T&L experience (Fig. 2) [14], and

it is at this design stage, where storyboarding may be a useful tool to design, test and implement the relevant content for such applications.

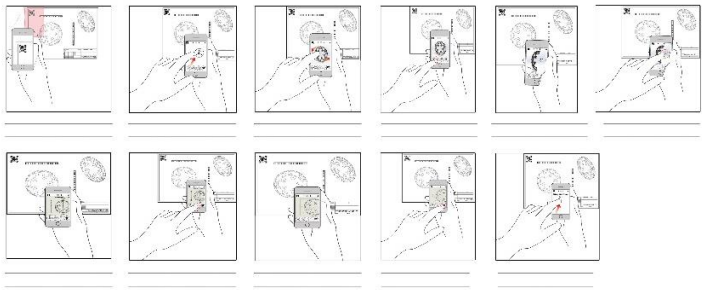

Fig. 3: Storyboard frames.

A storyboard is a short graphical depiction of a narrative (Fig. 3). Storyboarding is a tool originated in the contexts of production and filmmaking industry [30] but has found its way into Human Computer Interaction (HCI) for its practical way at demonstrating system interfaces and contexts of use within a complex narrative system [19]. Storyboarding can be used as a narrative tool to help anticipating a variety of T&L experiences for different users and in different context conditions.

Storyboarding in AR
During the design and development stage of any AR-based application, storyboarding offers the ability to capture the minds and behaviours of relevant stakeholders to transport/immerse them into the desired T&L narrative, allowing stakeholders to fully engage with the information presented by the story [16],[17]. Telling a story visually can also help overcome some issues related to dissimilar backgrounds in relevant stakeholders to facilitate the understanding of information and improve the outcomes [4],[20]. Therefore, a storyboard can become a communication tool to help teams move across the development of AR applications (Fig. 4). In this context, the major goal in visual storytelling is the successful communication of information within the system described in Figure 1.

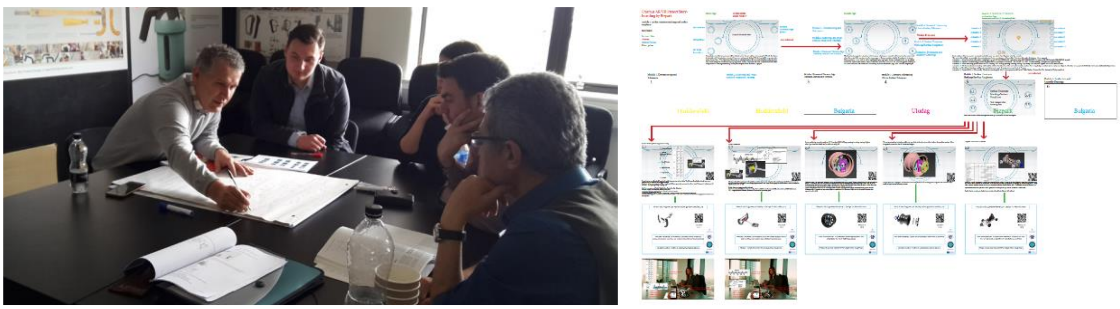

Fig. 4: Content planning through storyboarding.

How to tell a compelling story in AR
There are several elements involved in a good narrative, but based on Aristotle's earliest surviving work "Poetics" [2], the following 7 elements of storytelling can be applied to AR applications for pedagogic purposes developed through a Human-centred approach (Fig. 2):

- **Plot**: This relates to the problem the AR application or a section of it is aiming to solve. The problem needs to be thought thoroughly to be reframed [31]. For the sake of simplicity this could be referred as the desired T&L experience that the application is aiming for.
- **Character(s)**: These are the stakeholders/users involved in the T&L experience, not only students and lecturers, but anyone involved in the overall experience.

- **Theme**: This refers to the concept, the broad idea behind the designed section or overall AR application. This, outlines and articulates the plan to solve a problem.
- **Diction**: This element refers to the way the users/stakeholders will be addressed. The tone in which the users are addressed will influence their perception regarding the story, and consequently the overall AR application.
- **Melody**: Users tend to prefer recognizable patterns as they give a sense of knowledge and comfort. Melody, refers to the rhythm and the recognizable patterns set out in AR applications in a way that users may expect.
- **Décor**: This is basically the visual communication and additional graphic design elements considered to facilitate the storytelling process.
- **Spectacle**: No story will be complete without a twist or climax moment. This refers to the consideration of catchy, memorable and exciting elements that will stick into the users' minds and make the overall T&L experience more memorable.

Depending on the development stage the storyboard is being used, some of the above-mentioned elements may be more relevant than the others. On the other hand, the more the AR development advances, the more detail can be added, and the remaining elements could also be included in a more complex and detailed way using digital tools (Fig. 3), and through the use of some diegetic prototypes (Fig. 5) to help describe and present the solutions in a viable and credible way [21],[36].

Fig. 5: Diegetic prototype.

Conclusion: Storytelling moves people and projects forward

In any design process, iteration plays an important role in helping improve ideas. Storytelling through storyboards facilitates this iterative process as it helps people move forward through the presentation of compelling ideas. In this sense, persuasion plays an important role in communicating inspiring new ideas. In storyboarding, stories tend to fulfil a personal and emotional experience. It is not only about laying out lots of information into, but to also arouse the users' emotions.

Understanding how to best appeal to the user in an emotional level requires a human-centred approach, abductive thinking, and sense making to drive synthesis and to unveil the users' desires [23]. It takes rationality to understand what moves the user at an emotional level, but also some creativity to generate a compelling argument using storytelling. Storyboarding requires insight on the topic, knowledge and empathy with the user, and storytelling skills to present ideas with enough emotional power to be memorable. Iteratively improving the T&L experience using a low cost tool such as storyboarding helps test the pedagogic principles and other application features even before time and money are invested in fully developing the application (Fig. 6). This approach allows early validation cycles of iterative testing-improvement loops, and enough time to develop the application before going into the wild and no longer have control on how it is perceived and used by ever-larger sets of users.

Fig. 6: AR application in use.

The application of storyboarding brings together different user's requirements and needs, so that they can be kept at the core of the AR development. Storyboarding is easily used as a diegetic prototyping tool across the several stages of the AR development to help reconsider requirements and design features at early stages (pre-production stage) of the work. The use of this tool allowed the AR development to take a quick iterative dynamics within a human-centred framework where the different needs from the many stakeholders involved in the T&L experience required to be re-assessed and integrated into the design and development of the AR application.

References

[1] Aristotle: The Rhetoric of Aristotle: a Translation. Cambridge: The University Press, 1909.

[2] Aristotle: Aristotle's poetics. New York: Hill and Wang, 1961.

[3] Arslan, R.; Abdil, K.U.Ş.; Emreli, D.; Unver, E.; Huerta, O.: Investigation of the effects of using augmented reality apps on students' learning achievement and motivation in engineering drawing courses. Uludağ Üniversitesi Mühendislik Fakültesi Dergisi, 26(3), 2021, 787-798. https://doi.org/10.17482/uumfd.912061

[4] Botsis, T.; Fairman, J. E.; Moran, M. B.; Anagnostou, V.: Visual storytelling enhances knowledge dissemination in biomedical science. Journal of biomedical informatics, 107, 2020, 103458. https://doi.org/10.1016/j.jbi.2020.103458

[5] Bransford, J.; Brown, A.L.; Cocking, R.R.: How People Learn: Brain, Mind, Experience, and School: Nat, 2000.

[6] Brown, T.; Katz, B.: "Change by Design", Journal of product innovation management, 28(3), 2011, 381-383. https://doi.org/10.1111/j.1540-5885.2011.00806.x

[7] Cheng, K.H.; Tsai, C.C.: Affordances of augmented reality in science learning: Suggestions for future research. Journal of science education and technology, 22(4), 2013, 449-462. https://doi.org/10.1007/s10956-012-9405-9

[8] Chiang, T.H.; Yang, S.J.; Hwang, G.J.: An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. Journal of Educational Technology & Society, 17(4), 2014, 352-365. http://www.jstor.org/stable/jeductechsoci.17.4.352

[9] Council, D.: The design process: What is the double diamond. [online] The Design Council, 2015, Available at: https://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond (Accessed 21.11. 2021).

[10] Cross, K.P.: Opening Windows on Learning. The Cross Papers Number 2, 1998. https://eric.ed.gov/?id=ED420356

[11] Cross, K.P.: Learning Is about Making Connections. The Cross Papers Number 3, 1999. https://eric.ed.gov/?id=ED432314

[12] Felder, R.M.; Silverman, L.K.: Learning and teaching styles in engineering education. Engineering education, 78(7), 1988, 674-681.

[13] Ferrer-Torregrosa, J.; Torralba, J.; Jimenez, M.A.; García, S.; Barcia, J.M.: ARBOOK: Development and assessment of a tool based on augmented reality for anatomy. Journal of Science Education and Technology, 24(1), 2015, 119-124. https://doi.org/10.1007/s10956-014-9526-4

[14] Flechsig, K.H.: Kleines Handbuch didaktischer Modelle. Neuland-Verlag für lebendiges Lernen, 1996.

[15] Forlizzi, J.; Battarbee, K.: August. Understanding experience in interactive systems. In Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques, 2004, 261-268. https://doi.org/10.1145/1013115.1013152
[16] Green, M.C.; Brock, T.C.: The role of transportation in the persuasiveness of public narratives. Journal of personality and social psychology, 79(5), 2000, 701.
[17] Green, M.C.: Transportation into narrative worlds: The role of prior knowledge and perceived realism. Discourse processes, 38(2), 2004, 247-266. https://doi.org/10.1207/s15326950dp3802_5
[18] Häfner, P.; Häfner, V.; Ovtcharova, J.: Teaching methodology for virtual reality practical course in engineering education. Procedia Computer Science, 25, 2013, 251-260. https://doi.org/10.1016/j.procs.2013.11.031
[19] Hart, J.: The Art of the Storyboard: Storyboarding for Film, TV, and Animation, Focal Press, 1998.
[20] Hinyard, L.J.; Kreuter, M.W.: Using narrative communication as a tool for health behavior change: a conceptual, theoretical, and empirical overview. Health education & behavior, 34(5), 2007, 777-792. https://doi.org/10.1177/1090198106291963
[21] Kirby, D.: The future is now: Diegetic prototypes and the role of popular films in generating real-world technological development. Social Studies of Science, 40(1), 2010, 41–70. https://doi.org/10.1177/0306312709338325
[22] Kerawalla, L.; Luckin, R.; Seljeflot, S.; Woolard, A.: "Making it real": exploring the potential of augmented reality for teaching primary school science. Virtual reality, 10(3), 2006, 163-174. https://doi.org/10.1007/s10055-006-0036-4
[23] Kolko, J.: Abductive thinking and sensemaking: the drivers of design synthesis, Des. Issues, 2010. https://doi.org/10.1162/desi.2010.26.1.15
[24] Kuş, A.; Arslan, R.; Unver, E.; Huerta, O.; Dimitrov, L.; Tomov, P.; Tekin, Y.: An evaluation of technical drawings training needs for developing new training methods. In XXVII-th International Scientific and Technical Conference Automation of Discrete Production" ADP2018, 2018.
[25] McKee, R.; Story: style, structure, substance, and the principles of screenwriting, Harper Collins, 1997.
[26] Merchant, Z.H.: The impact of virtual reality-based learning environment design features on students' academic achievements. Texas A&M University, 2012.
[27] Meyers, F.D.: First year engineering graphics curricula in major engineering colleges. The Engineering Design Graphics Journal, 64(2), 2000. http://www.edgj.org/index.php/EDGJ/article/viewFile/146/142
[28] Nepal, K.P; Jenkins, G.A.: Blending project-based learning and traditional lecture-tutorial-based teaching approaches in engineering design courses. In AAEE 2011: Bridging sustainable community development and social justice: the next ethical challenge for humanitarian engineers: proceedings of the 22nd annual AAEE Conference on Engineering Education 5-7 December 2011, Fremantle, Western Australia, 2011, 338-343.
[29] Prince, M.: Does active learning work? A review of the research. Journal of engineering education, 93(3), 2004, 223-231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x
[30] Price, S.; Pallant, C.: Storyboarding: A critical history, Springer, 2015.
[31] Seelig, T.: How reframing a problem unlocks innovation, 2013.
[32] Steinhorst, R.K.; Keeler, C.M.: Developing material for introductory statistics courses from a conceptual, active learning viewpoint. Journal of Statistics Education, 3(3), 1995. https://doi.org/10.1080/10691898.1995.11910497
[33] Sotiriou, S.A.; Chatzichristou, E.; Savvas, S.; Ouzounoglou, N.; Dierking, L.D.; Sakari, S.H.; Hofstein, A.; Rosenfeld, S.: Connect: Designing the Classroom of Tomorrow by Using Advanced Technologies to Connect Formal and Informal Learning Environments. In CELDA, 2004, 432-436.
[34] Toda, M.: Emotion and decision making. Acta Psychologica, 45(1-3), 1980, 133-155.
[35] Unver, E.: Strategies for the transition to CAD based 3D design education. Computer-Aided Design and Applications, 3(1-4), 2006, 323-330. https://doi.org/10.1080/16864360.2006.10738470
[36] Wuyckens, G.: Design fiction as a critical inquiry method in media education: first findings of an exploratory research project, 2021.