8:e Utvecklingskonferensen för Sveriges ingenjörsutbildningar, Karlstads universitet,
24 november – 25 november 2021

An Assessment Review of Learning Performance when adopting Augmented Reality in Engineering Education

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Abstract — **Augmented Reality (AR) has developed rapidly in recent years and it is about to become a mainstream technology. We are witnessing how emerging technologies such as AR has been introduced and today widely applied in engineering education. The turmoil caused by the COVID-19 pandemic has in many ways highlighted the importance of AR technology for collaboration and remote assistance of frontline workers. Enabling experts to be much more productive in helping to debug problems and resolve production issues remotely. This kind of hands-on support and tutoring opportunities play well into the possibilities embedded in a more digitalized approach to engineering education. Still, both industries and universities are exploring ways to enhance the value-added credentials that come along with an integration and investment of AR. This paper set out to understand what type of assessment that are used to drive learning performance among students in engineering education.**

Learning assessment, augmented reality, systematic review

I. Introduction

ADOPTION of new technologies are symbiotic to enhancing and creating innovation derived from and within engineering education as this bind together authentic practices with forms of evidence-based approaches to change [1]. From a teacher's perspective such change is only possible if the value of adopting new practices is positively impacting student learning.

Understanding the how to adopt and properly learn from new technologies become critical, especially during societal digitalization transformation. Thus, it is important not only to start adopting new forms of teaching and learning but more so to outline consequences for digital forms such as Augmented Reality (AR) for student learning. Consequently, aspects relating to assessment becomes fundamental to better establish a harmonized adoption of AR and to enable a suitable toolbox for assessing learning experiences thereof.

Earlier research presents virtual prototyping and digital manifestations as a basis for increased cognition and collective understanding [2], that with adoption of AR face a growing risk for cognitive overload in learning situations [3], [11], [12]. The uncertainties of the effects is underlined as contradicting studies show the opposite, indicating that AR reduce cognitive load in STEM disciplines [25], [26]. Consequently, to what extent a new learning experience is enriched using augmentations is still not fully understood, and to what extent AR could provide guidance and support to more in-depth learning. As there are various AR applications, the assessment criteria for adoption of AR also appear diverse, which makes it difficult to choose proper criteria to evaluate the effectiveness of AR. In this work, we reviewed the assessment criteria for adoption of AR in engineering education. The aim of this work is to summarize, compare and find out the underlying commonalities of the assessment criteria.

II. Method and Results

A. Scientific Connection

In the general education area, the assessment criteria are mainly directed to the learning performance of students. There are various assessment criteria related to the learning performance and researchers usually group the criteria.

In the general education area, the assessment criteria are mainly directed to the learning performance of students. There are various assessment criteria related to the learning performance and researchers usually group the criteria. A related and sequential break-up into groupings is characteristic for criteria assessment [3], [4]. In addition, the major assessment criteria on AR in education come from mixed research method that combines both qualitative and quantitative methods [5].

In the engineering education area, the assessment criteria are not only related to the learning performance of students, which is regarded as general pedagogical aspects, but also related to the domain-specific learning aspects [6-10].

B. Method

We have reviewed the assessment criteria for adoption of AR in engineering education. The aim of this work is to summarize, compare and find out the underlying commonalities of the assessment criteria.

In detail, we searched the papers on 'AR engineering education' based on Web of Science Core Collection from 2016 to 2021, the past five years. Three search key words are 'AR', 'education', and 'engineering'. The intersection of search results based on key words of 'AR' and 'education', and 'AR' and 'engineering' are picked as the papers on 'AR engineering education'.

After obtaining the search results, we ranked the papers based on their yearly citation number, which indicates the influence of a paper, and selected the top 12 relevant papers for our literature survey.

The assessment criteria about learning outcome of AR engineering education utilized in these 12 papers are listed and the corresponding cognitive level based on Bloom's revised Taxonomy (BRT) [23] are generated.

C. Results

Results are shown in Table 1.

The metacognitive knowledge category in BRT [24] target potential of extra depth acquired via AR, e.g., the development of new metacognitive knowledge and metacognitive awareness. AR metacognitive knowledge can be exemplified by going from 2D to 3D, which gives a better overall picture and thus creates a better understanding of the task and at the same time allows an increased learning ability. AR show indications to drive instructional constructivist strategies potentially unlocking students to a new form of exploration space.

Creating interpretations and opportunies to discover simply by perceiving and interacting with information in a new format, thus promoting the self-construction of knowledge [3]. AR is a fairly new ingredient in educational contexts and is described in several articles as the key to an improved learning ability. One example is mentioned in paper [19] where Topographic Map Assessment (TMA) tests were performed and showed significantly improved learning ability with AR. Overall, AR show strong indication to increase student learning performance, still effectiveness were in some cases mere small and medium for students with average and low academic achievements while it was ineffective for students who demonstrated high academic achievement [12].

TABLE 1.
AR LEARNING OUTCOME ASSESSMENT CRITERIA USING BLOOM'S TAXONOMY

Paper	Subject	Assessment Criteria	Cognitive Level
P1[11]	Life Sciences, Earth Sciences, Mathematics, Physics	Investigating the affective domain during AR learning. Evaluating the influence of learner characteristics in the AR learning process. Designing an AR system for learning. Evaluating the effects of AR learning.	Remember (1) n*=18 Understand (2) n=3 Apply (3) n=2 Evaluate (5) n=1 Create (6) n=3
P2[12]	General, higher education	Does AR contribute to the learner Does AR increase student motivation Does AR contribute to special ability Does AR contribute to retention of knowledge	All (6)
P3[13]	Digital Art (STEM proj.)	Does AR contribute to technical skills, artistic skills and 21st Century skills**	All (6)
P4[14]	General, higher education	Does AR contribute to learning based on technology, applications, approaches Cognitive limitations of using AR Does AR contribute to academic achievement and learning attitude	
P5[15]	Architectural and Civil Engineering	Does AR increase graphic competencies and spatial skills	Remember (1)
		Does AR have great potential to be applied in construction projects	Apply (3)
		Does AR provide helpful instructional techniques to learn structural analysis	Analyse (4)
		Does AR improve students' understanding of building roof components	Understand (2)
		Does AR help students to expand their thinking in building-design processes	Create (6)
		Does AR improve the clarity of students' 3D perception	Remember (1)
P6[16]	Design	Does AR help students' perception of activity	Remember (1)
		Does AR help students' design generation	Create (6)
		Does AR help students' design assessment	Evaluate (5)
P7[17]	Electronic Engineering	Does AR help to understand resistive circuits	Understand (2)
		Does AR motivate students to investigate more about resistance circuits	Understand (2)
		Does AR help students know the basic concepts of building service engineering	Remember (1)
		Does AR help students comprehend the significance of indoor environment and climate conditions	Understand (2)
		Does AR help students apply the key design principles	Apply (3)
		Does AR help students analyse the power and energy demands of a building	Analyse (4)
		Does AR help students evaluate the significance and premises of environmental awareness in the design of building service systems	Evaluate (5)
P8[18]	Building Service Engineering	Can AR helps map users to develop their map-reading skills?	Remember (1)
P9[19]	Geography	Does AR help students mastering key difficult content areas of the class	Remember (1)
P10[20]	Mechanical Engineering	Does AR help comprehension and establishment of inter-space imagination	Understand (2) & Apply (3)
P11[21]	Postal Service	Does AR help students adapt to professional environment, have faster reaction to the tasks given, as well as achieve more accurate fulfilment of said tasks	All (6)
P12[22]	Primary Study	A wide range of evaluation parameters, such as time student spent paying attention and exhibiting problems, task performance, correct response rate.	All (6)

**n, distinct amount of cited cognition levels/article (review article)*
*** Social and Communication, Project Management, Problem Solving*

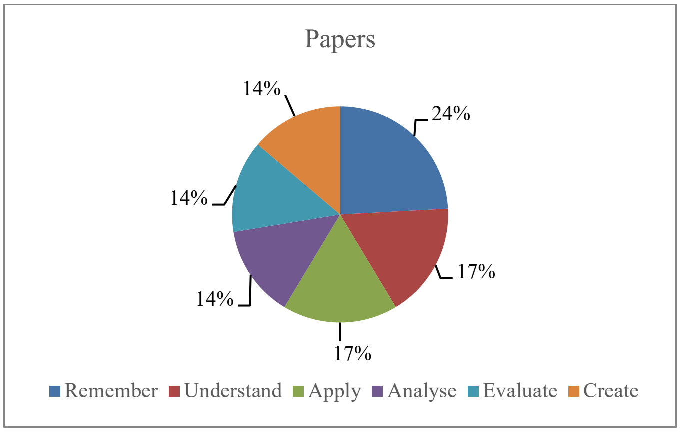

Fig. 1 Distribution of Bloom's cognition level in reviewed papers

III. Discussion and Conclusions

It is found that the assessment criteria about learning outcomes cover the full range of cognitive levels in Bloom's revised Taxonomy (Fig. 1). Yet, lower cognitive level is paid more attention than the higher cognitive level, which points out the direction for further development of AR in engineering education. As underlined in our research more efforts are needed, using diversified measures to include an assessment of deepened understanding that goes beyond remembering facts and content. The discovery process embedded in AR address that effective scaffolding mechanisms could well support student knowledge exploration and learning.

IV. Future Work

Advisable paths for future studies could be to determine the effectiveness of AR in different subjects, using a variation of instructional strategies. And also, increased understanding of how use cases/classes/activities could gain high-level cognitive outcomes over a sustained period of time. To assess the maturity-level of each paper, the cognitive level could be more in-depth analyzed by establishing a framework or an index that could strengthen strategies for instructional learning. In case of an index, the corresponding cognition levels could be mapped to better align with systematic implementation to level of courses and programs based on ILOs. For future research instructional techniques such as massive open online courses (MOOCs) or flipped classroom could also be potential ways to instrument learning support activities and also increase course participation. Last, as shown in this paper, although already too little research on how to introduce AR exists [13], even less exists in dealing with assessment leaving teachers ill-equipped and partly discouraged to utilize AR in the classroom. To strengthen student learning in future AR education efforts teachers require more support with didactic knowledge where sharing use cases become central to benefit locally and for the community in general.

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