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Drawings as a tool for assessing Mixed Reality Mobile Learning experiences: a case study on heritage education in Italian primary school

I Disegni come strumento per valutare le esperienze di apprendimento mobile in Realtà Mista: uno studio di caso sull'educazione al patrimonio nelle scuole primarie italiane

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Abstract:
In primary school, pupils often use drawings to express themselves, but it is rare for these drawings to be used to evaluate educational experiences. A study in Verona, Italy used drawings to better understand the impact of Mixed Reality (MR) technology on heritage education for 132 fifth-grade students. The study proposes a new method of analysis based on the frequency of specific subjects in the drawings and Jonassen's rubrics for assessing system dynamics models. The findings suggest that this method could be a useful tool for analysis and assessment, complementing other qualitative and quantitative data analyses.

Keywords: drawings; assessment; mixed reality; augmented reality; heritage education.

Abstract:
Nelle scuole primarie, gli alunni spesso utilizzano disegni per esprimersi, ma è raro che questi disegni vengano utilizzati per valutare le esperienze educative. Uno studio a Verona, Italia, ha utilizzato i disegni per comprendere meglio l'impatto della tecnologia di Realtà Mista (MR) sull'educazione al patrimonio per 132 studenti di quinta elementare. Lo studio propone un nuovo metodo di analisi basato sulla frequenza di specifici soggetti nei disegni e sulle rubriche di Jonassen per valutare i modelli di dinamica dei sistemi. I risultati suggeriscono che questo metodo potrebbe essere uno strumento utile per l'analisi e la valutazione, integrando altre analisi qualitative e quantitative dei dati.

Keywords: disegni; valutazione; realtà mista; realtà aumentata; educazione al patrimonio.

1. Introduction

During doctoral research to evaluate the impact of augmented and mixed reality technologies on heritage education, drawings were used to assess the understanding of the heritage in experimental and control primary classes in Verona, Italy. Classes took part in a visit to the Roman remains and monuments of Verona with teachers and a guide who led the visit. Control classes made those visits in the usual way, using a booklet, whereas the experimental classes used smartphones equipped with a Mixed Reality (MR) app. The guide led the visit, referring either to the booklet or the app. The idea of using pupils' drawings came while discussing the difficulties they might have in verbalising what they had learnt. Other tools, such as questionnaires and surveys, were used to gather quantitative data, thus assessing the child's satisfaction with the experience and recalling information and concepts about the Roman history of Verona. Still, the drawings were vital to map the different understanding of concepts and their attitude to the visit between pupils from experimental and control groups.

Although not widespread, using drawings as an assessment is a well-experimented practice in the educational field, especially in STEM subjects. However, more must be done about using it for cultural heritage education and for assessing mixed reality experiences. This paper proposes and applies a drawing assessment methodology of cultural heritage experiences based on Jonassen's et al. (2005) rubric for assessing system dynamics models.

2. Drawings as a tool for assessment

Although it is difficult to come to a shared definition of what a drawing is, it can be defined as an external model that involves the formation of an internal model (Quillin & Thomas, 2015, p. es2, 2). This model is created by selecting, organising and integrating information (Schwamborn et al., 2010). In particular, children's drawings have been used in the psychological field to express things they cannot verbalise. For trauma assessments, for example, drawings have proven significant in comprehending memories: these visual representations provide insights into experiences, perception and cognitive aspects related to traumatic recollections. They reveal that information processing can occur at a level even before putting experiences into words, so challenging traditional perspectives (Burgess & Hartman, 1993).

Only in the last few years have they been seen as ways in which children express their

understanding of the world (Stanczak, 2007). When the drawing of children involves conceptual knowledge, it represents the student's thinking, understanding, and change, including conceptual understanding (Anderson et al., 2014).

Notable applications can be seen in the realm of STEM. In a formative assessment approach, Bulunuz (2019) utilised the "annotated student drawing" strategy with sixth-grade students to evaluate their understanding of concepts like "pollination and fertilisation" and "the water cycle". This method shed light on how students structured their knowledge in science subjects and served as a tool for assessing conceptual understanding. Chang et al. (2014) employed digital drawing tools to explore how seventh-grade students understand chemical reactions, finding that teachers can assess students' ideas and understanding through drawing activities. Students' drawings have also been used to measure how preschool and kindergarten children perceive their schoolyard habitats, thus providing insights into their understanding of the environment (Cronin Jones, 2005). Finally, Margoudi et al. (2016) employed drawings to assess how the EcoFactory serious game influenced students' understanding of sustainability and contemporary manufacturing practices. Their findings supported the hypothesis that drawings can offer insights into complex topics like sustainability.

From a meaning-making perspective, drawings proved to help capture children's perspectives on the transition from preschool to primary school in Iceland and Australia. Results demonstrated that drawings could convey nuanced meanings through verbal and visual language (Einarsdottir et al., 2009). Furthermore, Scott & Weishaar (2008) presented empirical evidence supporting the effectiveness of using "Talking Drawings" as a classroom assessment tool for evaluating student comprehension in Higher Education.

To sum up, a substantial body of research emphasises the effectiveness of using drawings as assessment tools across domains (Dove et al., 1999; Glynn & Duit, 1995).

Drawings have proven to be diagnostic tools in various areas, such as trauma, scientific understanding, environmental awareness and educational adjustments. They bridge the gap between non-verbal communication and connect explicit and implicit cognitive processes. This solidifies their position as assessment methods. This paper proposes a methodology to use drawings as an assessment tool for cultural heritage education experiences.

3. Methodology

In the field of education, achieving meaningful learning is a highly desirable outcome of any teaching intervention. According to the principles of constructivist epistemology, there are four key characteristics that must be present for meaningful learning to occur: active participation in authentic learning tasks, reflection on personal and social meanings, collaborative teamwork, and a willingness to learn (Howland et al., 2014).

Jonassen, Strobel, and Gottdenker (2005) assert that conceptual change is a prevalent and contemporary approach to meaningful learning, which involves constructing and reorganising personal conceptual models. The process of drawing can externalise these models, making it possible to analyse them using the "rubrics for assessing systems dynamics models" proposed by Jonassen et al. (2005) (see Figure 1) where applicable. By creating a checklist of features that indicate the internalisation of concepts, one can assess the effectiveness of the drawing as a tool

for meaningful learning. It is also essential to pay attention to the differences in drawings between the experimental and control groups.

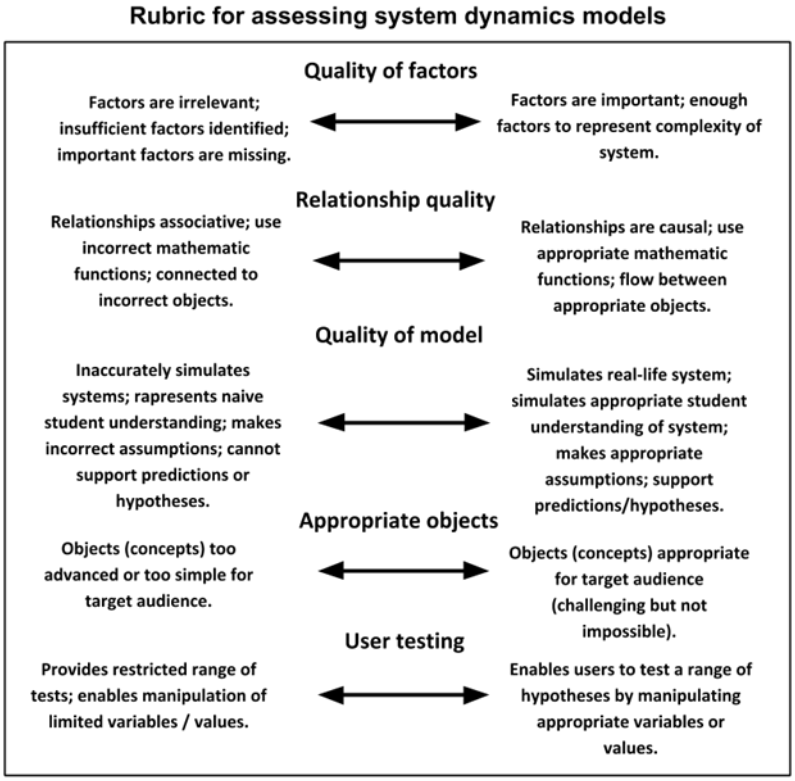


Figure 1. The rubric for assessing system dynamics models proposed by Jonassen et al. (2005). We used the necessary dimensions in this model to assess and compare students' drawings.

This study focused on 5th-year primary school children between the ages of ten and eleven in Verona, Italy. Three primary schools were selected based on their willingness to participate in the research. From each school, a fifth-grade class was chosen, and the teachers of these classes agreed to participate in the project. A quasi-experimental design was used, with each experimental class having a corresponding "parallel class" as a control group. These parallel classes comprised students in the same grade and school who shared programs and sometimes teachers. By selecting parallel classes as control groups, the study aimed to minimise the impact of external variables.

There follows Table 1 with the population involved:

Table 1 - *Classes involved in the study.*

Class	Section	Name of the School	Research	Number of pupils
5	A	Camozzini	Control	27
5	B	Camozzini	Experimental	17
5	A	Dall'Oca Bianca	Control	16
5	B	Dall'Oca Bianca	Experimental	19
5	B	Rosani	Control	16
5	A + C	Rosani	Experimental	22 + 15
			TOT	**132**

All the classes went on a trip to see the ancient Roman ruins and landmarks in Verona. Each class was accompanied by two teachers, and a single guide conducted all the visits. The control classes used a booklet for their visits, while the experimental classes used smartphones with an MR app. The guide provided the same information for both groups, either referencing the booklet or the app. The booklet and app contained the same pictures and details, except that the app allowed MR. The visits lasted the same amount of time and followed the same trail for both experimental and control classes. They covered the following monuments: the Arena, Gallieno's Wall, Lions' Gate, Piazza Erbe (Roman Forum), Piazza dei Signori (Roman Street and Sewer), Roman Bridge and Theatre, Amon Jupiter Arch, Borsari's Gate, Vicolo Guasto (another part of Gallieno's Wall), Gavi's Arch. All of them were present both in the booklet and in the app, although only the Arena, Lions' Gate, Borsari's Gate and Gavi's Arch in the app were AR/MR enabled. The day after the visit to Roman Verona, the teachers asked the students from both experimental and control classes to draw their favourite thing from the trip and give it a title or brief description. This qualitative approach allowed for a better understanding of the quantitative results and provided new insights into the internalisation and acquisition processes. The drawings, which were based on visual perception, interaction with the guide and peers, and the use of a mediating artefact (the booklet or the AR/MR app), represented a unique way for students to externalise their experiences. Ninety drawings were collected and analysed to determine if AR and MR technology impacted the students' attention or interest in different subjects. Subsequently, the drawings were analysed by applying a variation of the rubrics to assess system dynamics models adapted for the analysis of drawings (Figure 2). The adaptation is based chiefly on adapted 'quality of factors', 'relationship quality' and 'quality of model' dimensions. We did not find 'appropriate objects' and 'user testing' applicable to this particular context.

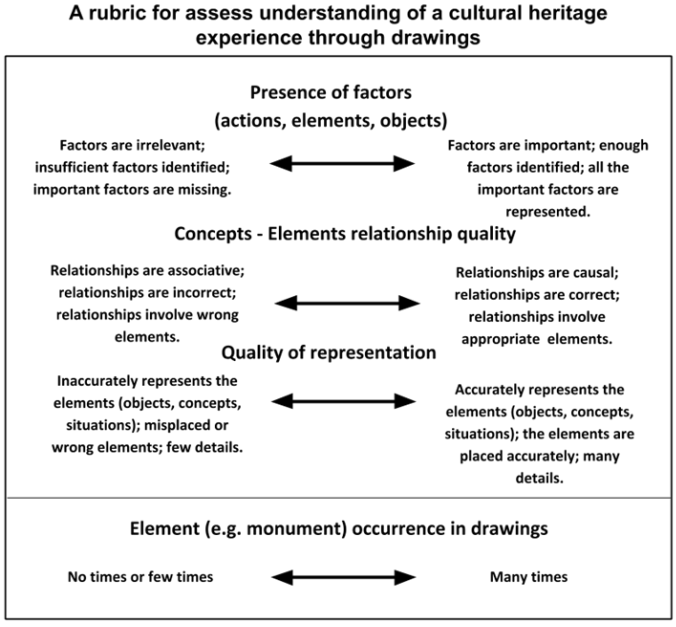


Figure 2. The rubric for assessing understanding of cultural heritage through drawings.

4. Results and Analysis

4.1. Element occurrence in drawings

The Arena of Verona was by far the most commonly drawn monument (43% in the experimental [Exp] and 40% in the control [Con] group), followed by the Gavi's Arch (14% Exp, 22% Con) but, those apart, differences emerged between the experimental and control groups. While the Bridge and Theatre stopover in the control group had the same weight as Gavi's Arch (22%), it had less relevance in the experimental group (5%). The opposite was true for Borsari's Gate (14% Exp, 7% Con). Those differences demonstrate the influence of MR technology in changing the pupils' focus from some stopovers and aspects to others. In particular, the gates are not well known and monumental like the Arena and the Roman Bridge and Theatre stopovers, but they attracted much more attention in the experimental group. Borsari's Gate is represented in drawings of the experimental group twice as much as in the control group (14% against 7%). Lions' Gate is represented twice in the experimental group, whereas, in the control group, it does not appear at all. The Roman city organisation is not present in the drawings of the control classes. In contrast, the experimental classes produced drawings dedicated to city organisation alone (10%) and inside drawings of other subjects. Only a few experimental group members drew the monuments as they were in the past (11.9%), while no one in the control group did it. Two drawings of the Lustral Jupiter Temple used to be in front of Borsari's Gate, one of the Arena, one of Lions' Gate, and one of Gavi's Arch. Overall, the experimental group represented a wider variety of monuments. For further analysis, let us focus on the Arena stopover, where the experimental group used MR technology and the control group used the booklet. A total of 32 drawings representing the Arena have been gathered, of which 16 were control and 16 experimental.

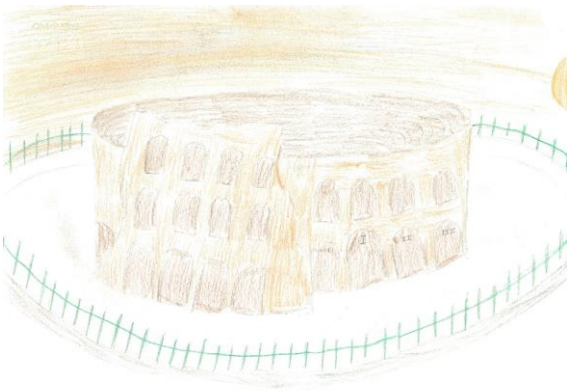
4.2 Presence of factors

Both control and experimental groups have remembered and represented many factors in their drawings, although there are differences between the two groups. Figures 3 (experimental group) and 4 (control group) can serve as examples here. For instance, in Figures 3-1 and 3-3, the old perimeter of the Arena is present. Three experimental (18.8%) and two control groups (12.5%) drawings recorded this information. Both the groups show they retained the information about the Arena's structure, two arches tall, and the 'wing', which is the rest of the highest wall, which was three arches tall, nowadays collapsed for the most part. There are four drawings per group (25%) where pupils depict themselves, their classmates and/or the guide. Only the experimental group (in six drawings, 37.5%) depicted non-human elements which are not part of the monument itself but that are part of the broader context of the place and the situation, like the capital in Figure 3-2, the fountain in Figure 3-3 and the houses in Figure 3-4.

4.3 Concepts/Elements relationship quality

In many pictures drawn by both control and experimental groups, the details reveal an understanding of complex concepts, often different between the two groups. The experimental group demonstrates a better understanding of the concept of the old perimeter of the Arena and of it being two metres lower than the actual ground level (see Figure 3-1 and 3-3). Also, the

experimental group shows the attention that lacks in the control group to the context of the guided visit. Pupils from both groups depicted themselves, their classmates and the guide using MR devices during the visit. However, in the experimental drawings, several individuals are depicted in the act of doing something and showing emotion. For example, in Figure 3-3, the girl depicted herself using the MR device and smiling during the visit. In Figure 3-4, pupils are smiling or attentive, looking around and following what the guide is explaining. At the same time, the two who are using the headset are represented in an amazed 'jaw-dropping' expression. In Figure 3-3, the girl demonstrates perfect comprehension of the environment and the position where we stopped to use MR devices.

1. 

2. 

3. 

4. 

Figure 3. Drawings of the experimental group

The view from above of herself, the Arena and the fountain placed in the correct relative position confirms it. In Figures 3-4 and 4-3, we can see a gate larger than the others, which, as the guide explained, is the main gate of the Arena. Two drawings (12.5%) in the control group and five in the experimental (31.3%) represent this element. Only in a drawing (Figure 4-3) can one see the details of the upper *arcovoli* (arches in the Arena's structure) bricked over, highlighting that students understood the history of the monument and the different uses made of those arches throughout the centuries (houses, shops and stores). The presence of a pool inside the Arena (Figure 4-2) in something three pupils in the control group (18.8%) and no one in the experimental one has retained. It is linked to the concept of the complex system that is used to gather and drain rainwater from the Arena.

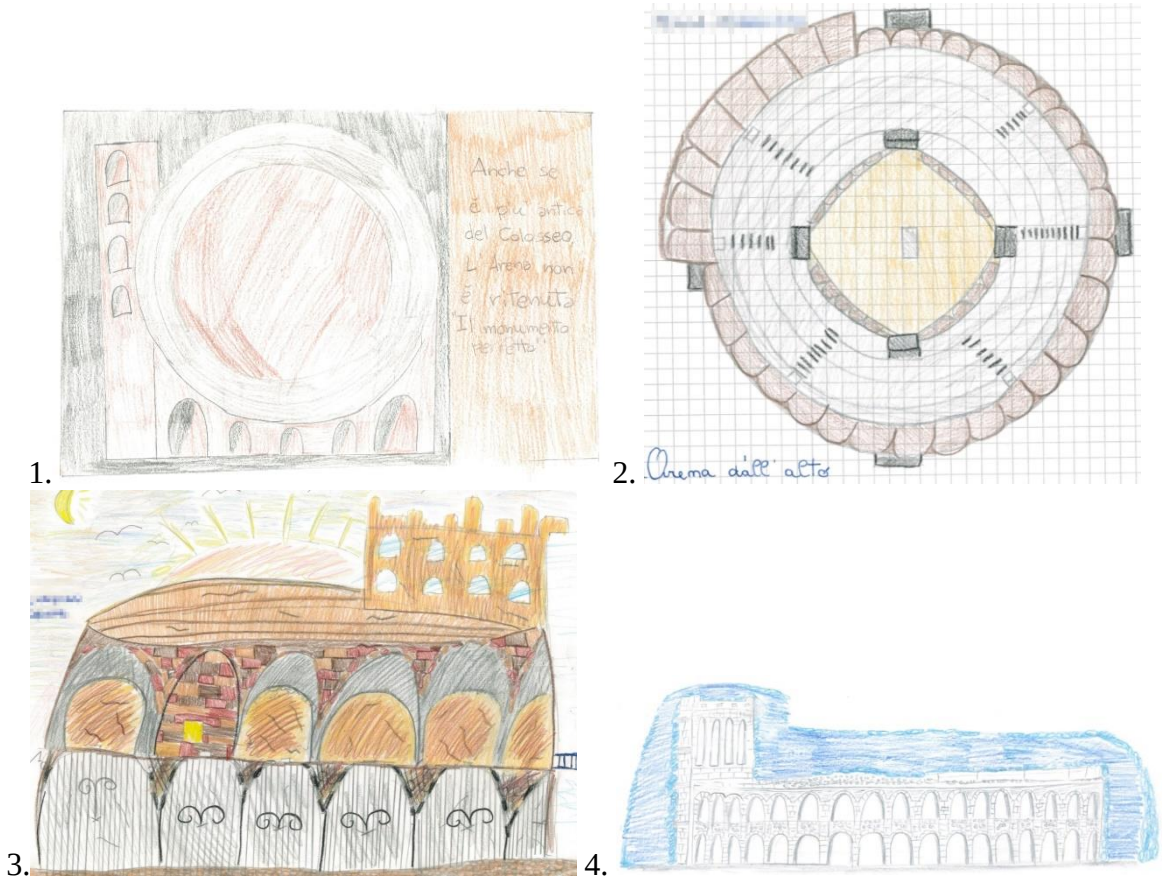


Figure 4. Drawings of the control group

4.4 Quality of representation

Looking at drawings made by experimental and control groups, coherent, group-specific characteristics became apparent. One of them was the different representation of monuments. In the experimental group, the monuments were drawn with a higher resemblance to the original and with a more precise projection of the three-dimensional object on the two-dimensional paper medium. That is true only for stopovers, like the Arena, where the students used MR technology. In the control group, most representations seemed based on two-dimensional projections of two-dimensional models. In Figures 3 and 4, it is easy to see the pattern. While the mental model regarding the Arena seems three-dimensional in the experimental group (Figure 3), in the control group (Figure 4), it seems to be two-dimensional or at least a less refined three-dimensional one. At the same time, control group drawings are more lavish in details regarding the monument. As mentioned, the experimental group seems to have focussed more on the general context and situation of the stopover.

5. Discussion

In summary, as for the presence of factors, there is only one significant difference between the experimental and control group: the presence of objects and elements of the environment near the monument. They are present in many of the experimental group's drawings and absent from

the control group's. Concerning the quality of the relationship between elements in the drawing and concepts, the experimental group performed better in representing the context – made of environment, actions and emotions -. In contrast, the control group focused more on the monument's details. Those details add quality to the general representation but cannot fill the gap that the usage of MR technology created. Indeed, the experimental group seemed to have a better internal model than the control one, a three-dimensional model compared to the two-dimensional control model. Overall, for what concerns the visit to the Roman remains in Verona, the analysis of the drawings highlights three areas of improvement ascribable to the use of MR technology:

- Context awareness and the relationship between elements of the context.
- Quality of internal (mental) models of monuments (3D vs 2D)
- Highlighting the importance of lesser monuments

Only one aspect has been better without MR technology:

- Focus on the details of the monuments.

Part of those results confirms other research outcomes, notably that MR interaction allows students to understand concepts better (Yoon et al., 2012) and enhances spatial abilities and awareness (Akçayır & Akçayır, 2017; Stanton et al., 1996). Also, the fact that MR use can enhance mental models, highlighted by Cheng & Tsai (2013) and confirmed by Behmke et al. (2018), is confirmed by this study.

Two results of this research are new in the literature. The first one is the fact that the MR app raised the level of context awareness of students. Specifically, their attention was focused not only on the monument as a single object but on the whole monument context, including other smaller monuments nearby, buildings and landscape elements. The other side of this medal is that the experimental group focussed less on the monument's details as a single object. The control group was better at representing details. This may relate to the fact that the MR app used 3D models of the monuments, which were not very detailed. Having access to archaeologically precise 3D models would probably improve this aspect. Finally, MR technology allowed students to appreciate monuments that usually would have been overlooked. The reason is found in the MR app's characteristic of highlighting and allowing meaningful interactions with all the monuments in the visit, not only the physically bigger and well-known ones.

6. Conclusion

Using drawings not only allowed to assess understanding but also to gather valuable feedback on the experience. Notably, feedback on the preferred monument was expected, but several unexpected emotional feedbacks were recorded and unintended feedback about the technology's interference in the visit. The adaptation to drawings and cultural heritage of the rubric for assessing system dynamics models seem to work correctly in this context, which is confirmed by the fact that some of our results confirmed the results of other studies.

Drawings are confirmed to be a powerful tool to use, especially with young students, because they allow them to express themselves and what they saw and learnt in a way that would hardly be possible with words. In particular, they make visible an internal model that would be otherwise hidden from the teacher or expressed only partially.

Thinking about further research employing the drawing analysis would be interesting to interview the children about their drawings or ask them to produce a complete description of what is inside in order to understand all the dynamics and elements in the drawing fully. Currently, there is research involving primary and lower secondary schools in Italy on using mixed reality in the classroom and other contexts such as museums. It would be essential to assess the impact of MR technology on the understanding of curricular subjects, and drawings might be one of the best tools for teachers and researchers.

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