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Mobile Augmented Reality in Science Teaching: an analysis of the pedagogical usability with pre-service teachers

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Abstract. This article presents the results of a pedagogical usability evaluation with pre-service teachers about an application for Science teaching developed with educational resources in augmented reality. The evaluation of the application was carried out through a quality evaluation model of educational software for Science teaching, considering the Pedagogical, Science Teaching, and Usability aspects.

Keywords: Science Teaching · Pedagogical Usability · Pre-Service Teachers · Mobile Augmented Reality · Mobile Learning.

1 Introduction

Augmented reality (AR) was recently addressed in the report presented by the New Media Consortium [2]. In this context, it is possible to note that research on AR in education is evolving quickly [1].

A variant of AR technology is the Mobile Augmented Reality (MAR) technology [3]. Mobile devices are indicated to have a positive impact on both teachers and students in that it positively affects the duration of their attention, learning and training tenacity, and their attitudes towards collaboration and interaction [8]. MAR initiatives have been making inroads in the training and learning domain, as learning approaches can be virtually accessed using the ubiquitous mobile devices, in which learners can access learning materials and contents anywhere, anytime on their mobile devices [6].

It is important to emphasize that the construction of educational applications with technological resources related to MAR also needs to be articulated from a pedagogical point of view. Christensen et al. [5] point out that in parallel to the use of the computational resources offered by this type of environment, the present focus on the educational side, which must be articulated by the teacher, becomes essential and must be carefully established and organized.

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Among the various points to be considered when projecting and constructing a MAR approach is how the design of the environment will be interconnected to its educational objectives. It should be clear the form and context in which each learning situation will be applied. According to Lakkala et al. [7], this could be called pedagogical usability, i.e., correspondence between the systems design and the educational environment, situation, and context in which it will be used.

The pedagogical usability of a system and/or learning material is also dependent on the goals set for a learning situation by the student and teacher [9]. Regarding the pedagogical usability criteria for digital learning materials, the most common pedagogical usability features are learner control, possibility for cooperative or collaborative learning activities, explicit learning goals, authenticity of learning material and learner support (scaffolding) [10].

Chiu et al. [4] explain that physical laboratory experiments in science enable students to interact with observable scientific phenomena, but students often fail to make connections with underlying molecular-level behaviors. Virtual laboratory experiments and computer-based visualizations enable students to interact with unobservable scientific concepts, but students may find it difficult to connect with actual instances of the phenomenon observed.

The purpose of this article is to investigate how the pedagogical usability of MAR educational resources is seen by teachers in training in science teaching. In order to do so, experiments were carried out using MAR educational resources for the teaching of sciences and applied modules of a pedagogical usability evaluation questionnaire to infer the results from this experiment, aiming at answering the following research questions (RQ):

- RQ1: What are the pedagogical aspects related to the use of MAR educational resources in Science Teaching?
- RQ2: How do pre-service teachers perceive the use of MAR educational resources in Science Teaching?
- RQ3: What is the opinion of pre-service teachers about the usability aspects of MAR educational resources in Science Teaching?

2 Methodological Procedures

2.1 Research Design

Participants attended two on-site meetings in an IT lab of the educational institution in the second semester of 2018. The meetings lasted one hour and forty-five minutes each. In the first meeting, the participants were introduced to the avatAR UFRGS app. The test coordinators helped the participants install the MAR app in their smartphones.

The second meeting was characterized by the use of the avatAR UFRGS app. The participants were instructed on how to use and interact with the science simulations, settings and variables configurations to play and interact with the AR simulations. At the end of the second meeting, after participants had interacted with the app, a user experience analysis questionnaire regarding this type of approach was applied.

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2.2 MAR app for Science Teaching

The avatAR UFRGS app is an educational technology that provides students with interactive simulations developed in MAR. In the app, students have access to various educational resources, where they can visualize micro and macroscopic physical phenomena and interact with multimedia resources such as images, videos, 3D objects and simulations.

In relation to the pedagogical potential of the MAR app, some of the available resources for students to interact with are visual simulations, access to multimedia resources, interaction and storage of experiments in the students inventory, as well as access to the experiments without the need to connect to the Internet.

The avatAR UFRGS app was used to provide participants with the visualization and interaction of educational simulations, which enables students to change parameters and verify the changes that result from their actions. The content that participants had access to during the meetings was about basic Science, where they were given the orientation to visualize the experiments, interacting with the simulations, and checking the associated multimedia resources.

2.3 Participants

The participants of this research are pre-service teachers studying for the Degree in Natural Sciences offered by the Federal Institute of Rio Grande do Sul, in the discipline of Information and Communication Technologies in the Teaching of Natural Sciences (40 class hours). Although the course is located in the field of Natural Sciences, this course aims to present to the student teachers how technology can be used in teaching in the context they are inserted and, therefore, being considered an appropriate discipline for this experiment to be carried out.

Nineteen student teachers participated in this study and the demographic profile of the participants is: 14 female (9 in the age group of up to 29 years old and 5 in the age group between 30 and 50 years old) and 5 male (all up to 29 years of age). All participants reported having a smartphone and/or a tablet to install the avatAR UFRGS app, as well as Internet access. As previously mentioned, this course presents to students new possibilities of using technologies in their teaching practice, however, the participants had not yet had contact with technological resources of MAR or with the app used during the experiment, having some knowledge about this area.

2.4 Tools and Collected Data Analysis

By the end of the second meeting, a test was applied to the nineteen participants, comprising thirty multiple-choice questions related to their first impressions while using the AR app, considering that none of them had ever used this kind of technology before. The answer options were placed according to the model proposed in the Likert scale, defined as follows: Fully disagree; Partially disagree; Indifferent; Partially agree; and Fully agree. It is important to highlight that the creation of the forms was made using the Google Forms app.

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The questionnaire comprised thirty multiple-choice questions (each question provided an optional open-ended question for participants to write a justification for their answers) to gather information about their opinion on the use of the AR app, difficulties and advantages identified during the experiment. The data collection instrument used was PECTUS (Pedagogy, Science Teaching, Technology, and Usability), which consists of a model of quality evaluation of educational software for science teaching composed of four dimensions of evaluation: Pedagogy, Teaching of Sciences, Technology, and Usability [11]. For the evaluation of the pedagogical usability of the avatAR UFRGS app, only the Pedagogy, Science Teaching, and Usability dimensions were used. Finally, a qualitative analysis of the results was performed based on the descriptive statistics of the results obtained through the PECTUS collection instrument.

3 Results Analysis

RQ1: What are the pedagogical aspects related to the use of MAR educational resources in Science Teaching? In order to answer the research question on aspects of pedagogy related to the use of the AR app by the teaching professors, ten pedagogical attributes of educational software quality were evaluated in science teaching: Affectivity, Flexibility, Cognitive Load, Conceptual Reliability, Collaboration Support, Objectivity, Teacher Support, Student Control, Motivation, and Accommodation of Individual Differences. Each of these attributes is defined in Table 1, presenting the average (Avg) of the answers obtained with the participants and their standard deviation (SD).

Analyzing the results of the evaluation module related to Pedagogy aspects, we can observe that the global average was 4.27. This value characterizes the MAR app positively for this requirement, since the teachers recognize the affectivity (average 4.1) and flexibility (average 4.5) of the app. However, student teachers understand that the MAR app offers a relatively high cognitive load for a learning resource (average 3.6), although it presents good evaluations in conceptual reliability (average 4.2), collaboration support (average 4.3) and objectivity of the app (mean 4.4). The MAR app also presented good performance in the questions involving control by the user (average 4.2), causing motivation necessary for learning (average 4.4) and accommodating the individual differences (mean 4.1). Regarding teacher support, the results show the efficiency of the MAR app in teacher support in educational activities (mean 4.9). In general, the standard deviation for this case was considered normal, not having too many dispersions in any attribute, except for the item related to the cognitive load, which obtained a standard deviation of 1.1.

RQ2: How do pre-service teachers perceive the use of MAR educational resources in Science Teaching? To answer the research question on the dimension involving the aspects of science Teaching, ten attributes of software quality were evaluated by the teaching professors, which were: Support to Concepts construction, Support for the Application of Concepts, Support for

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Table 1. Evaluation of the Pedagogical aspects.

ID	Questions	Avg	SD
Q1	Affectivity - It refers to the exposition of physical and psychological aspects and behaviors, capable of indicating the user's involvement when using the software, such as: emotion, states of humor, motivation, anxiety, feelings of anger, disinterest, joy, etc.	4.1	0.9
Q2	Flexibility - It refers to the ability of accessing the software, the access for people with disabilities and to educational teaching such as: self-learning, objectivism, constructivism, etc.	4.5	0.5
Q3	Cognitive Load - It refers to the mental effort required during the execution of the tasks in the software, such as exploitation of the contents, use of the structure, demanded responses, etc.	3.6	1.1
Q4	Conceptual Reliability - It refers to the software's ability to arouse reactions and behaviors that express confidence in the contents and results that it provides.	4.2	0.8
Q5	Collaboration Support - It refers to the support provided by the software for conducting activities in a collaborative way, supporting the sharing of knowledge and the development of social skills.	4.3	0.7
Q6	Objectivity - It refers to the way the software works and the procedures incorporated in it, i.e., how well defined and standardized they are.	4.4	0.7
Q7	Teacher Support - It refers to the level of support the software provides to the teacher, which will enable him to act as an information provider and/or facilitator of learning.	4.9	0.3
Q8	Control by the Student - It refers to the possibility offered by the software to the users, to define how to explore the modules and contents, that is, deciding which sections to study, which paths to follow, which material to use and the order involved in those decisions.	4.2	0.8
Q9	Motivation - It refers to the ability of the software itself to motivate users to explore themes and concepts through elements such as multimedia resources, good quality interaction, etc.	4.4	0.6
Q10	Accommodation of Individual Differences - Refers to the ability of the software to consider and facilitate the accommodation of individual student differences, i.e., reinforces heterogeneity in terms of previous attitudes, knowledge and experience, learning styles, etc.	4.1	0.7

Evolutionary Learning, Empirical Support, Association between Theory and the Real World, Support for Representation of Theory and Concepts, Precision of Calculations and Results, Scientific Rigor, Clarity of Procedures, and Support for Problem Solving. Each of these attributes is defined in Table 2, presenting the average of the answers obtained with the participants and their SD.

Regarding the results about science teaching, we can observe that the overall mean of the dimension assessment was 4.33. The attributes recognized by student teachers in the MAR app indicate that the technology supports the construction (mean 4.6) and application of science concepts (mean 4.4), contributes to student evolutionary learning (mean 4.3) and is presented as an empirical support resource (mean 4.1). According to the results, we can also infer that the MAR app provides an association between theory and the real world (mean 4.6), support for representation of theory and concepts (mean 4.4), precision of calculations and results (mean 4.3), scientific rigor of the information presented (mean 4.0), as well as clarity of procedures (mean 4.3) and support for problem solving (mean 4.3). In general, it is important to note that the standard deviation for this case was considered a little high in relation to the previous dimension, in which several requirements, such as Support for the Application of Concepts

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Table 2. Evaluation of the Science Teaching aspects.

ID	Questions	Avg	SD
Q11	Support to the Construction of Concepts - Refers to the construction of abstract concepts into more concrete concepts. It emphasizes the formation of concepts and promotes conceptual change.	4.6	0.5
Q12	Support for the Application of Concepts - Refers to the simplified application of reality, making abstract concepts into their most important elements.	4.4	1.0
Q13	Support for Evolutionary Learning - Refers to the growing learning that assists in understanding concepts from simpler stages to more complex phenomena.	4.3	0.7
Q14	Empirical Support - Refers to activities that make explicit the nature of scientific research and its theories.	4.1	1.0
Q15	Association between Theory and the Real World - Refers to understanding about the real natural world, interacting with underlying scientific models that could not be inferred through direct observation.	4.6	0.7
Q16	Support for Representation of Theory and Concepts - Refers to visual information such as formulas, results, 3D models and feedback to improve understanding of concepts.	4.4	0.7
Q17	Accuracy of Calculations and Results - Refers to the collection, generation and testing of large amounts of data to prove a hypothesis.	4.3	1.0
Q18	Scientific Rigor - Refers to the identification and relation between cause and effect between "complex systems", proven with criteria of scientific nature.	4.0	1.0
Q19	Clarity of Procedures - Refers to the reduction of cognitive "noise" so that students can use simple commands to focus on the concepts involved.	4.3	0.9
Q20	Problem Solving Support - Refers to support for problem-solving skills and to promote critical and analytical reasoning.	4.3	0.8

and Empirical Support, obtained a standard deviation of 1.0, indicating a high in dispersion around the assessments of student teachers.

RQ3: What is the opinion of pre-service teachers about the usability aspects of MAR educational resources in Science Teaching? In relation to the evaluation of the dimension involving Usability aspects, ten attributes of quality of educational software were evaluated by the student teachers, being: Software Adequacy, Learning Ease, Operationality, Memorization Support, Error Protection, Clarity of Information, Accessibility, Design Quality, User Satisfaction, and General Functionality. Table 3 presents the average of the answers obtained with the participants and their SD.

The results related to the evaluation of attributes of the dimension of Usability Aspects reached the global average of 4.24. The obtained results characterize the positively MAR app for this requirement, since the student teachers considered the app to be adequate (mean 4.5), it offers learning ease (average 4.6) and memorization support (average 4.1). However, the subjects understand that the MAR app offers a low operability (average of 3.9) and protection of user errors (average 3.6), although they consider that the app presents clarity in the information (average 4.2) and accessibility (mean 4.0). In general, evaluators believe that the app offers design quality (average 4.5), satisfies user interaction (average 4.6), and is useful in terms of overall functionality (average 4.5). In this dimension case, the values obtained in the standard deviation are similar to the

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Table 3. Evaluation of the Usability aspects.

ID	Questions	Avg	SD
Q21	Software Adequacy - Refers to the software's ability to enable the user to understand whether the software is appropriate for their tasks or not.	4.5	0.8
Q22	Ease of Learning - Refers to the facility offered by the software so that the user learns to explore and use the different modules and activities included.	4.6	0.8
Q23	Operability - Refers to the ability of the software to make its handling easy for users.	3.9	0.9
Q24	Memorization Support - It refers to the characteristics (standardization of screens, navigation, design, etc.) that facilitate the user memorization of the paths and interaction procedures for proper use of the software.	4.1	1.0
Q25	User Error Protection - Refers to the features that the software has in order to protect the user from making possible errors.	3.6	1.0
Q26	Clarity of Information - Relates to whether or not the information contained in the knowledge space incorporated in the software is presented in an understandable way.	4.2	0.9
Q27	Accessibility - Refers to the ability of the software to be used by people with different profiles and characteristics, in a specific context linked to the objectives of the system.	4.0	1.2
Q28	Design Quality - Understands aspects such as appearance and layout of the elements in the software screens, including text, icons, graphics, colors, etc.	4.5	0.7
Q29	User Satisfaction - Represents a subjective condition, according to which the user considers the interaction with the application pleasant and attractive, feeling satisfied with the software.	4.6	0.5
Q30	General Functionality - Represents a comprehensive dimension, related to the usefulness of the software and meeting the goals intended by the users.	4.5	0.6

first dimension, and there are no high differences to be highlighted, except for the Operationality and Protection to User Errors attribute, which indicates a divergence between the student teachers' evaluations.

4 Conclusion

For MAR educational resources to potentially become educationally beneficial, several aspects need to be taken into account at the time of their design and development, such as aspects related to pedagogical usability. In this way, this article sought to highlight how the pedagogical usability of MAR educational resources is seen by teachers in training in Science Teaching.

Based on the experiment carried out with teachers in the area of sciences, it was possible to evaluate the pedagogical usability of the MAR educational resources of the avatAR UFRGS app. In order to organize the discussion about the objective of this article, three research questions were defined, which enabled us to obtain the degree of the pedagogical usability perceived by student teachers regarding MAR educational resources in the dimensions of Pedagogical Aspects (global mean 4.27), Teaching Aspects of Sciences (global mean 4.33), and Aspects of Usability (4.24). Through what was presented in the discussion of the results, it is possible to affirm that the MAR educational resources evaluated by the teachers in training attended the most common pedagogical usability characteristics in digital learning material, defined by Nokelainen [10] as learner control,

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possibility for cooperative or collaborative learning activities, explicit learning goals, authenticity of learning material and learner support (scaffolding).

In this way, the results in a general scope could be considered positive, given that the participants identified through answering the questionnaire that the app has an adequate pedagogical usability, well structured and with potential benefits to the teaching practice. Aspects of improvement and usability difficulties have been identified in fewer quantities, but essential to be considered in the future improvements to be implemented in the app. Therefore, as future aspects of this research are the improvement of the items listed in the app, as well as the execution of research related to the impact that this type of approach has in the area of sciences for teaching and learning.

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