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LEARNING RESOURCES IN ANATOMY BASED ON AUGMENTED REALITY

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ABSTRACT
The intersection between the 4th industrial revolution technologies and Media, Information and Digital Literacy (MIDL) promotes the critical use of ICT in the classroom. Augmented reality can be applied in different areas of knowledge, and one of the most explored fields has been health. Educative activities report a considerable presence of its application for learning processes. This work aims to present the results obtained from evaluating learning resources developed using augmented reality technology. Students of health undergraduate programs who participated in the Academic Day of the Biomedicine program evaluated the resources; they all belong to a Brazilian higher education institution. Eight educational resources were evaluated, all related to the area of general anatomy. The resources were evaluated by 41 students who answered a validated questionnaire to evaluate educational resources with questions about learning, interactivity, engagement, attractiveness, functionality, and autonomy. The evaluation was considered valid. The challenge is to find interactive alternatives that stimulate and simultaneously incorporate content with a depth appropriate to the subject's objective. Critics in the evaluation will serve as the basis for adjustments in the next learning resources to be developed. In addition, PCA, correlated question checking, and Exploratory Factor Analysis (EFA) techniques were applied to verify the quality of the survey and group respondents into segments.

Author Keywords
Augmented reality; general anatomy; learning resource.

INTRODUCTION
The general anatomy course is basic to all graduate programs in the health area and deals with the study of the structural organization of the human body from the point of view of morphology and arrangement and the relationships between organs and systems. Seeking innovative solutions for teaching, the research group in adaptive intelligent environments (GAIA) proposes the use of modern didactic resources —based on interactivity and the use of three-dimensional visualization— based on a technique known as augmented reality [7].

Media, Information, and Digital Literacy (MIDL) in different social contexts promotes people's critical capacity concerning the sources and content of information with which they interact in their daily activities. Under the MIDL approach, it is necessary to recognize the new conditions generated by the 4th industrial revolution and involve these technologies in the classroom according to the expectations framed in the approach. Augmented reality opens important ways for active learning and offers resources that motivate and promote critical and creative thinking in students.

Augmented reality (AR) can be defined as the addition of virtual objects to the physical environment, presented to the user in real-time with the support of a technological device, using an interface of the real environment adapted to visualize and manipulate real and virtual objects. AR is a technology to enrich the perception of reality, being a potentiator of the five senses with which the human being perceives reality. AR allows complement reality with a digital environment; in more technical terms, AR groups the technologies that allow the superposition of virtual information on real objects [1].

The use of augmented reality applied to health has been the target of research in recent years. A brief search was conducted in Medline on articles that refer to the use and development of educational resources that use augmented reality technology, seeking to know the reality in the health area. The search equation used was *"augmented reality" AND "education"*. Only 170 articles were found, published between 1997 and 2018, arranged as presented in Figure 1. There is a growing interest in the use of this technology in health education. Although there is a growing trend in the number of works in this area, the number of published articles is low, which shows that

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there is room for developing proposals involving the use of augmented reality in education.

Some medical areas, such as medical education and training, surgical simulation, neurological rehabilitation, psychotherapy, and telemedicine, use augmented reality techniques. Several works are being developed to implement visualization systems with augmented reality to provide accessible and user-friendly interfaces that support medical interventions and present patient information [2, 11]. An example is the tool developed for visualization and simulation of cardiac signals [9]. Support for teaching the interpretation of ultrasonography images [10] and in teaching and personalized rehabilitation of patients [3] are two other examples of the use of augmented reality in healthcare teaching. Bioinformatics is another area of healthcare that has been benefiting from augmented reality tools for 3D visualization of models of biochemical structures [4]. In college education, [5] seek to know the opinion of students on the application of augmented reality in their learning process. Nevertheless, it is verified that there are still challenges to be addressed, which is why augmented reality in healthcare offers several research opportunities.

One of the challenges in using active learning methods is presenting the problems to the students so that they can work and study the contents at any time and in any place. In health courses, augmented reality technology seems to be adaptable as a content development strategy. However, it is necessary to assess students' perceptions about the relevance of AR in their learning process. This work presents an evaluation of educational resources for learning human anatomy. The guiding principle of this work is to bring students closer to human anatomical pieces in a presentation close to the reality they are used to, in an interactive way that allows stimulating and persuading students to deepen their knowledge on the proposed topic.

This paper presents the evaluation of 8 educational resources related to general anatomy. The rating of these resources seeks to establish whether the educational resources serve as a tool to support the learning process and their capacity to increase students' motivation. Forty-one students participated in the evaluation of educational resources. The evaluation of the resources was done by rating 15 statements with scores between 1 and 5. In the end, students are asked to answer three open-ended questions about their experiences.

This document is structured as follows: in the previous paragraphs the research area is presented, in the section 2 the principle of operation of the educational resources and the tools used for their development are presented. In section 3 the details of the evaluation conducted are presented, as well as the questionnaire applied. The results obtained are discussed in the section 4. Finally, the conclusions and future work are presented in the section 5.

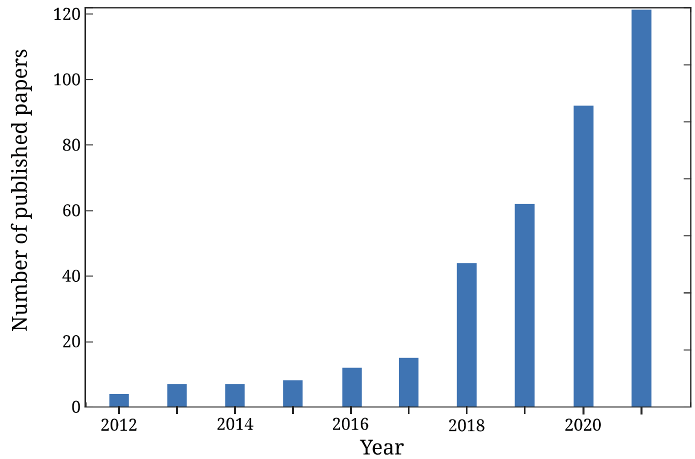


Figure 1: Number of articles found with the search engine *pubmed* with the search equation: *"augmented reality" AND "education"*.

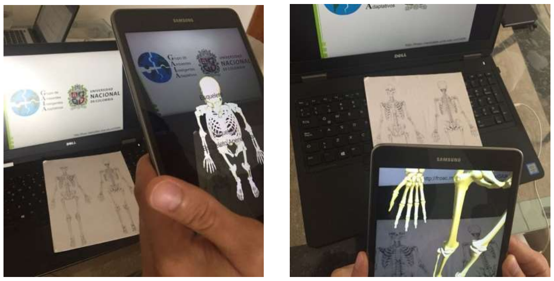
DEVELOPMENT OF AUGMENTED REALITY EDUCATIONAL RESOURCES

In order to offer educational alternatives that motivate students to acquire new knowledge in the classroom, educational resources have been developed in different fields of study, including health. In previous works of the Research in Adaptive Intelligent Environments (GAIA) group of the National University of Colombia Manizales headquarters [6, 7], augmented reality educational resources have been built in areas of natural sciences, social sciences and computer science. Specifically, in the area of basic anatomy, several learning resources are available, stored, described and available in the federation of learning resources repositories Colombia (FROAC). There are different tools for the development of resources based on augmented reality; the following were used for the presented objects: 1) Unity 3D, Vuforia, Android Studio and 3ds Max.

The available augmented reality objects must be executed in a mobile device or emulated environment, achieving interaction with the resources through triggers (markers or images), such as the one shown in figure 2. For each of the learning resources, there is an activator allusive to its content. The interaction is performed by taking advantage of the information obtained from the mobile device's inertial sensors in conjunction with the relative position of the marker. In addition, 3D object exploration is allowed with functions such as zoom and rotation. An example of one of the educational resources is presented in Figure 2.

MATERIALS AND METHODS

This work aims to have students in the health area evaluate learning resources with augmented reality. From the results, we seek to know the relevance of using the developed resources and possible improvements to enhance the learning process. To evaluate the educational resources, a form developed in [6] was applied. Eight educational



(a) Marker detection. (b) Zoom functionality.

Figure 2: Educational resource related to the skeletal system. Marker detection and the use of the zoom functionality are presented.

Figure 3: Students interacting with the learning resources.

resources in the area of general anatomy were selected to be evaluated by health students. These are part of a set of educational resources with augmented reality developed as part of a project by the GAIA group [6, 7]. Three undergraduate students and one master's student participated in the construction of the educational resources while carrying out other project activities with a 1-year linkage.

The learning resources were evaluated by 41 students from the biomedicine program of the Universidade Federal de Ciências da Saúde de Porto Alegre (UFCSPA) aged between 19 and 24 years. Each one was asked to interact with the learning resources they were interested in and fill out a form considering their experience. This form evaluates each educational resource in the educational, aesthetic, functional, and content dimensions. The questions grouped in the educational dimension assess the contribution of the resource to student learning. The questions that make up the aesthetic grouping aim to inquire about the students' opinion of the user interface and its ability to motivate them to access the educational content. The functional dimension seeks to rate the student's experience regarding their interaction with the user interface and its effectiveness in allowing them to access the educational content; it also aims to evaluate the platform's ability to provide an effective interaction with the content in case of failures. Finally, the questions grouped in the content dimension seek to inquire about the subjective relevance of the content presented by the educational resource.

Through the form, participants were invited to rate 15 statements according to the following ratings: totally agree (5), partially agree (4), neither agree nor disagree (3), partially disagree (2), totally disagree (1), not applicable (N/A). In addition, they were asked to add comments about what they liked most about the educational resource, what they liked minor and additional observations. The table 1 presents the statements rated for each of the interactions with the educational resources. Figure 3 shows students interacting with one of the educational resources.

The content validity of the questionnaire was endorsed by experts in the group and the Cronbach's reliability coefficient 0.943 was calculated. Cronbach's reliability coefficient α was calculated, resulting in 0.943. The minimum acceptable value Cronbach's alpha coefficient is 0.7 and greater than 0.8 is considered to have high internal consistency [8].

RESULTS AND DISCUSSION

The evaluation form groups 15 statements into four dimensions: educational, content, aesthetic and functional. The rating of these resources in the last two dimensions obeys the objective of applying new technologies in the classroom: to increase student motivation in the learning process. High scores on these dimensions may imply a higher engagement on the part of the students.

The goal of educational resources is to support the learning process. Thus, rating the educational and content dimensions allows evidence of the latter's achievement. In addition, the evaluation of the latter seeks to quantify the perceived relevance of the resources. High scores in the educational dimension imply that the resources contribute to learning, are consistent with their objective, and offer feedback to the student to facilitate his or her learning process. Higher scores in the content dimension imply consistency between what the user expects to find and the content offered. Through this dimension, the importance of the content for the evaluator of the resource can be quantified.

Figure 4 shows box plots of the evaluations of each of the statements for 5 educational resources. The results for the resources digestive system, skeletal system and respiratory system are not presented because they only received 1, 1 and 2 evaluations, respectively. The educational resources that received the highest number of evaluations were those related to the muscular system, with 11, and the circulatory system and heart, each with 7. Among the 41 evaluations performed, 5 do not rate a specific educational resource and are not presented in the ratings per educational resource.

Table 1: Statments assessed by the students.

Dimensión	Statement
Educative	1. The content of the educational resource is in line with its objective. 2. The content of the educational resource contributed to your learning. 3. The educational resource provided the necessary feedback to understand the topic presented. 4. The educational resource generated more interest in the topic after using it.
Aesthetic	5. The colors and their contrast, the images, the size of the elements and the layout of the space facilitated their interaction with the educational resource. 6. The appearance of the educational resource (color contrast, distribution of elements such as text, images, tables, etc.) is pleasing. 7. The user interface design implicitly or explicitly indicates how to interact with the educational resource. 8. Font and text size and text size is readable and allowed a good reading speed.
Functional	9. Access to the content of the educational resource was allowed. 10. It was easy to interact with the educational resource. 11. The educational resource presents some kind of help or instructions to guide navigation through the content. 12. Buttons and links are easy to find and quick to perform the required action. 13. In the event of an error or failure, the educational resource allowed you to continue from the point where you were before the error occurred.
Content	14. The content of the educational resource is relevant to your life, personal goals and interests. 15. The educational resource was related to what you expected to find in it.

The statements that, on average, had the best and worst ratings were *"'The content of the educational resource matches its purpose"* and *"'In the event of an error or failure, the educational resource allowed you to continue where you were before it occurred"* with 4.98 and 3.79, respectively. Table 2 presents the averages of the 41 assessments for each of the dimensions, in addition to the overall average. The average age of the students who participated was 21 years old.

The educational resource related to the heart scored between 4 and 5 points for statements 1 to 10. For this same resource, the first quartile of evaluations for the statement *"Buttons and links are easy to find and quick to perform the necessary actionÓ* is between 1 and 3 points. For statements 10, 11 and 12, related to functionality, a median of 4 was obtained, with quartiles 3 and 4 grouped between 4 and 5 points. In the case of the human body educational resource, the statements *"Buttons and links are easy to find and quick to perform the necessary action"* obtained a median of 3 points with a minimum score of 1 point.

The educational resource circulatory system obtained the lowest ratings in the statements *"'The design of the user interface implicitly or explicitly indicates how to interact with the educational resource"* and *"'Buttons and links are easy to find and quick to perform the necessary action"*. Although the first of the above statements had a median of 4 points, 25% of the evaluations were below 3 points. For the second statement, 50% of the evaluators scored below 3 points. Both obtained a minimum score of 1 point.

The resources "skeletal system" and "muscular system" obtained evaluations between 3 and 5 points for all statements. The ratings obtained for statements 1 to 4 stand out in both resources.

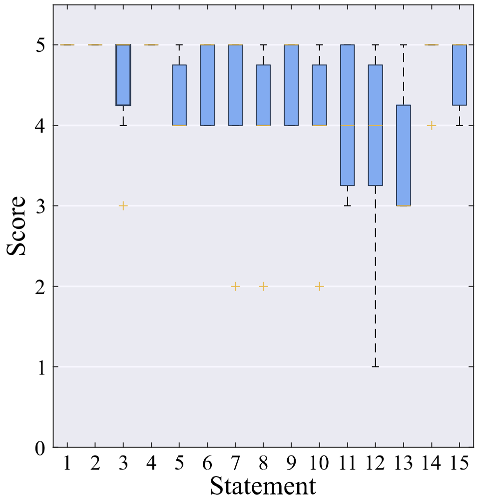
Table 2: Averages of the evaluations by dimension and overall score

Dimension	Average
Educative	4,89
Aesthetic	4,20
Functional	4,20
Content	4,67
Global average	4,49

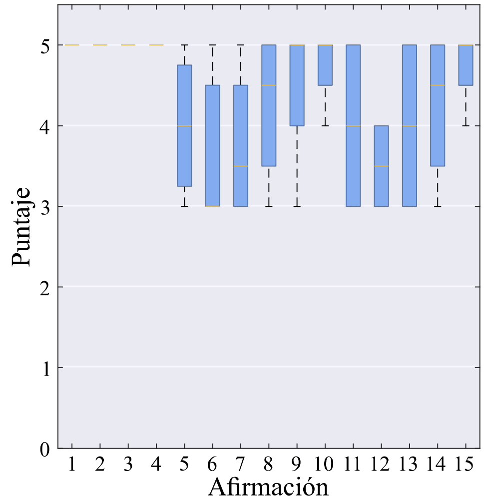
The questions related to the educational and content dimensions obtained scores between 4 and 5 points in all cases. In addition, for each object, 50% of the evaluations in questions 1 to 4 are grouped in a score equal to 5.

In figure 7 the results of the evaluations are synthesized through box plots, presenting the average scores per dimension and grouped by learning resource. Those evaluations that did not mention a specific educational resource are grouped in an additional graph. 50% of the evaluations for each object were rated with a score of 5 among the statements related to the educational dimension. Quartiles 3 and 4 are between 4 and 5 points for all learning resources regarding the content dimension.

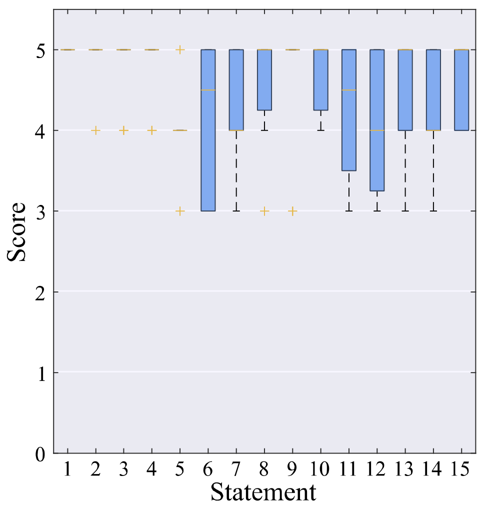
In the evaluations that did not specify an educational resource, the educational, aesthetic, and functional di-



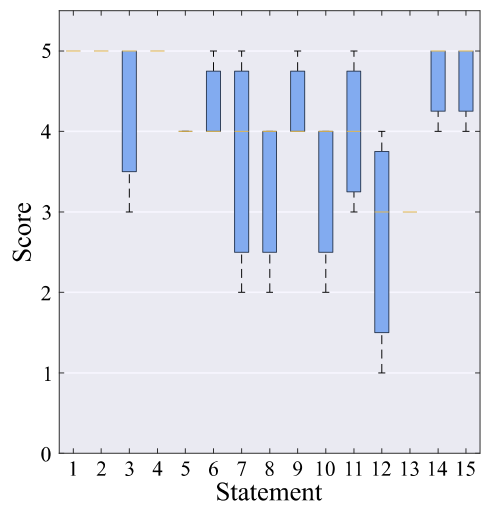
(a) Heart, N=7.



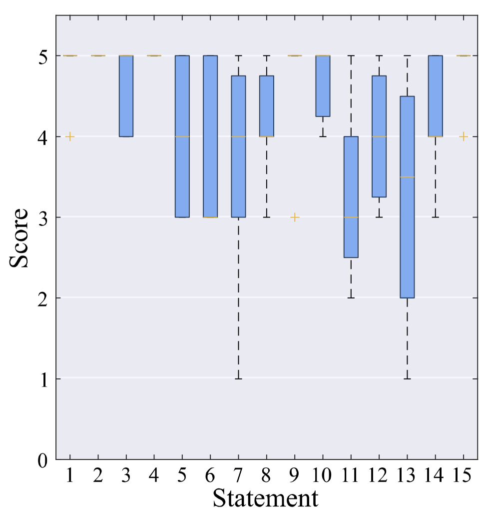
(b) Skeletal system, N=4.



(c) Muscular system, N=11.



(d) Human body N=3.



(e) Circulatory system, N=7.

Figure 4: Box plot of the evaluations of each of the statements, grouped by learning resource.

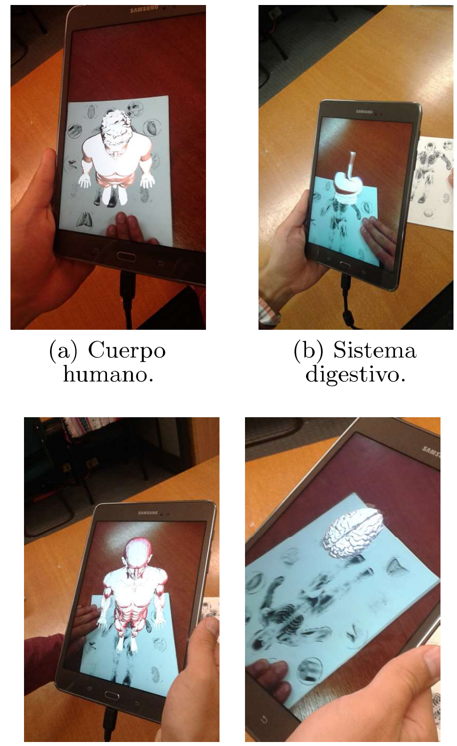
Figure 5: Marcador del recurso educativo *cuerpo humano*.

mensions obtained a median of 5 points. In this case, the functional dimension had lower scores.

The aesthetic and functional dimensions presented more dispersed ratings than the others. On the other hand, only the educational resources heart and muscular system have a median above 4 points for the aesthetic dimension. However, for the same dimension, quartile 4 of all objects is above 4 points. In the functional dimension, the resources circulatory system, skeletal system, and muscular system obtained a median above 4 points. On the other hand, the human body resource had all the evaluations grouped below 4 points for all dimensions.

Among the results obtained, the ratings in the aesthetic and functional dimensions stand out for the educational resource "human body", which stands out for its complexity when compared to other resources. It incorporates different systems and allows the visualization of each one through user interaction with the marker. Each of the 10 circular areas, which allow interaction, represents: the respiratory system, the skeletal system, the male reproductive system, the muscular system, the brain, the visual system, the digestive system, the endocrine system and a representation of the body of a male human. To switch between each of the models offered by the content, simply limit the passage of light on the corresponding region as if each of the regions were a button to be pressed. Figure 5 shows the marker for the educational resource "human body". Figure 6 shows some of the alternative views that this resource allows.

The low scores of this resource in the functional dimension can be explained by the way in which the interaction is performed. By default, the resource presents the bone system and the visualization of the other models depends on holding down the corresponding region. This feature can make it difficult to rotate and zoom the educational resource. In this one, each of the different display options are consistent in terms of size and relative position. Thus, negative ratings in the functional dimension may be related to the relative position of the user when making transitions. Smaller models require zooming in order to improve rendering. In some cases, this situation may not have been noticed by users.



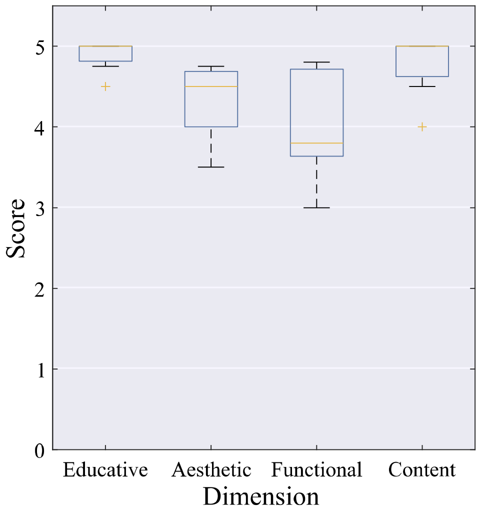
(a) Cuerpo humano. (b) Sistema digestivo. (c) Sistema muscular. (d) Cerebro.

Figure 6: Vistas alternativas para el recurso educativo *cuerpo humano*.

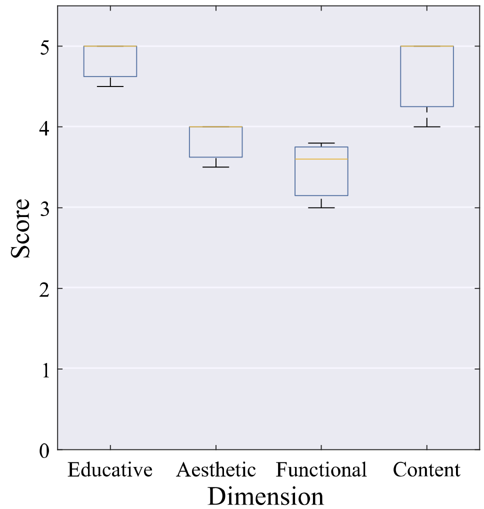
Survey segmentation analysis

A segmentation analysis were applied to verify the quality of the survey and grouping respondents into populations, the following steps were performed: 1) Check the scale of the data set, 2) a principal Component Analysis (PCA) to assess the robustness of the survey and ability to pool the data, 3) checkup of the correlated questions, 4) an observation of the final segments obtained by exploratory factor analysis (EFA). Python sklearn and factor_analyzer libraries were used for the modeling statistics and the grouping of surveys, respectively. The Survey Validity was evaluating with PCA, to determine if the survey to group respondents into various segments. Figure 8a show the eigenvalues of the features and at least 4 have a value greater than 1. After confirming the eigenvalues, we evaluate the number of features explains a large portion of the variance (threshold 80%), as can be seen in the Figure 8b.

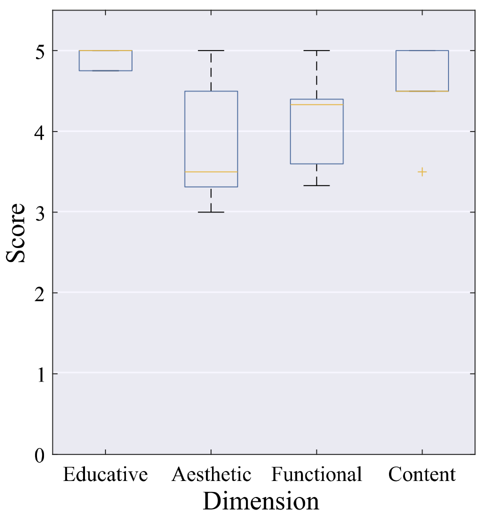
Finally, in the survey validation reviews that the components of the PCA are showing types of different populations. If all populations include the same characteristics, then the survey is not segmenting the population well. The table 3 shows that the populations are very different.



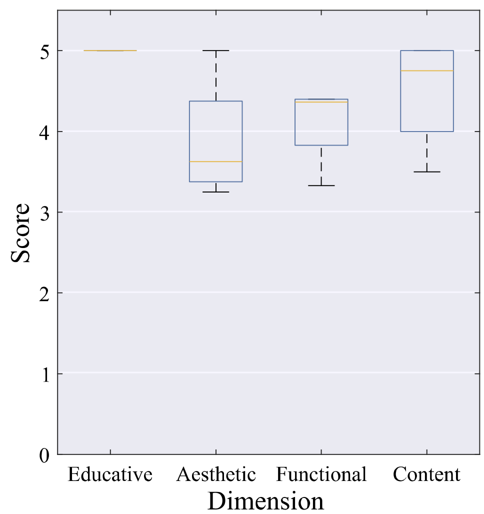
(a) Heart, N=7.



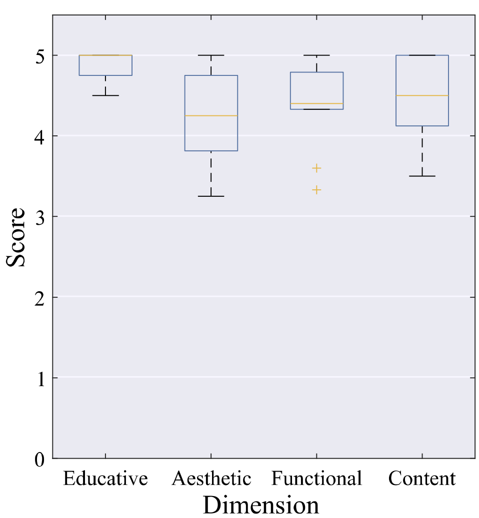
(b) Human body, N=3.



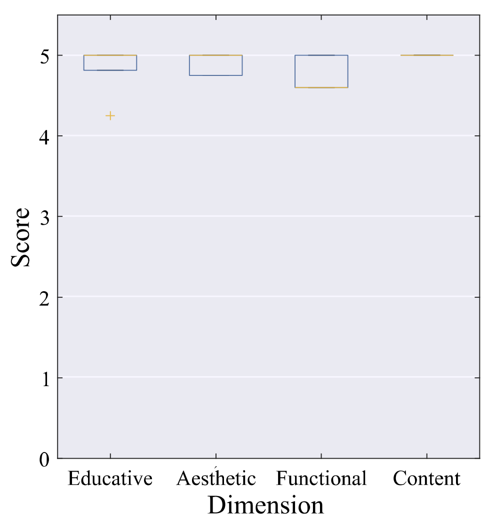
(c) Circulatory system, N=7.



(d) Skeletal system, N=4.

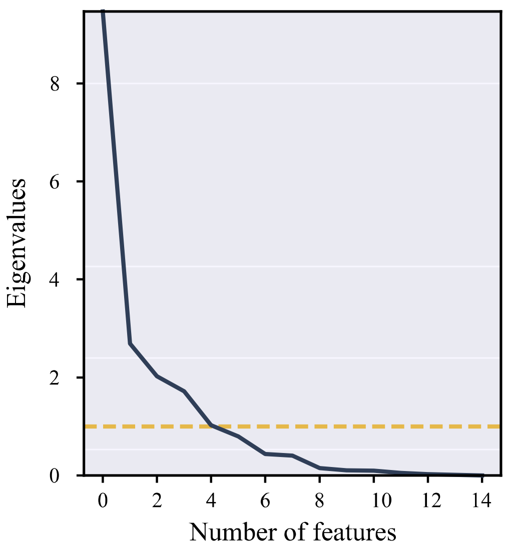


(e) Muscular system, N=11.

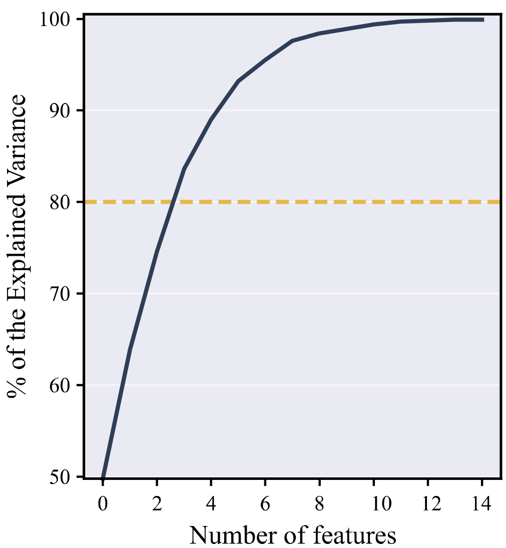


(f) Unspecified educational resource, N=5.

Figure 7: Box plot of grade point averages by dimension, grouped by learning resource.



(a) PCA eigenvalues.



(b) Proportion of variance explained.

Figure 8: Results of the PCA analysis

Table 3: Features for each component and populations.

	1st Max	2nd Max	3rd Max	4th Max
PC-1	4	15	1	2
PC-2	3	13	7	11
PC-3	11	7	13	15
PC-4	7	3	11	6
PC-5	3	11	14	5
PC-6	11	12	1	9
PC-7	5	8	14	3
PC-8	6	13	12	3
PC-9	12	5	13	15
PC-10	8	9	6	4
PC-11	14	12	7	2
PC-12	6	10	14	1
PC-13	9	7	5	1
PC-14	1	10	4	14
PC-15	10	11	4	14

As an additional analysis, correlating statements was carried out. When highly correlated statements are found, it means that the responses of a user to these will be the same, and the impact on the results or the importance of this correlation should be analyzed. The heat map in the Figure 9 shows that there are no high correlations.

To analyze the respondents as segments, which can give us an idea of their behavior regarding the characteristics investigated, EFA (Exploratory Factor Analysis) was applied to create our segments. First, with the list of the eigenvalues, our factors were mapped. Then, it is recommended to create five segments and a new model to observe the reflection of each characteristic in each segment. For the analysis of the segments, only those in which the values obtained with Factor Analysis exceeded the positive or negative value 0.5 were taken, obtaining the table 4. Finally, these results were combined to get closer to the categories defined in the survey and the segments renamed to match the interests reflected by the statements in the survey.

These factors explain 66,10 % of the variance. This analysis allows us to appreciate that users have different preferences regarding educational content, but that in order to meet expectations, resources must be designed and built taking into account educational characteristics and content, aesthetic and functional.

Comments

At the end of the evaluation, students were asked to add comments about what they liked most about the educational resource, what they liked the least and additional observations. The most recurrent comments about what they liked most were related to the 3D visualization, interactivity, and zoom functionality. Participants liked the details of the 3D models, the ability to explore the model by moving the mobile device, and the ease of studying the subject with this type of resource.

Table 4: Segments with relationship greater than 0.5

	Content_Esthet	Functional	FeedBack_Guide	Educat_Obj	Educat_Learn
1	NaN	NaN	NaN	0.938538	NaN
2	NaN	NaN	NaN	NaN	0.99576
3	NaN	NaN	0.652031	NaN	NaN
4	NaN	NaN	NaN	NaN	NaN
5	0.909373	NaN	NaN	NaN	NaN
6	0.902584	NaN	NaN	NaN	NaN
7	NaN	NaN	0.506923	NaN	NaN
8	NaN	0.757656	NaN	NaN	NaN
9	0.618083	0.587243	NaN	NaN	NaN
10	NaN	0.879725	NaN	NaN	NaN
11	0.765808	NaN	0.548746	NaN	NaN
12	NaN	0.762469	NaN	NaN	NaN
13	0.508675	NaN	NaN	NaN	NaN
14	0.759294	NaN	NaN	NaN	NaN
15	NaN	NaN	NaN	NaN	NaN

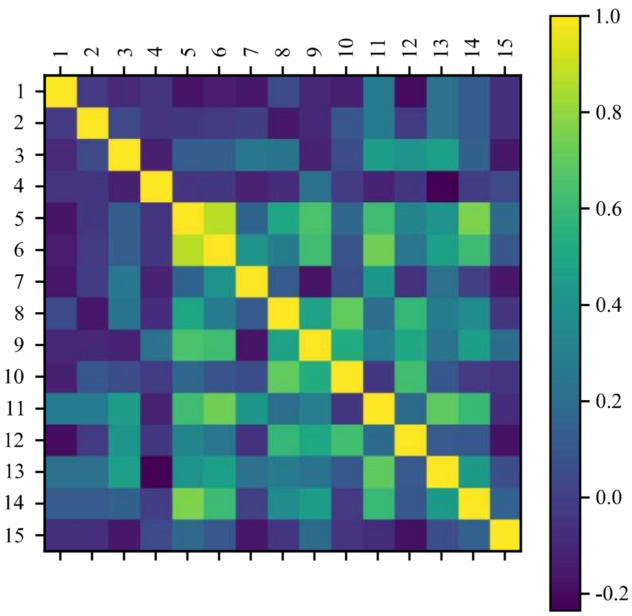


Figure 9: Correlations heatmap between statements.

In the responses about what they liked least about the resources, they found: poor image stability, a lack of precision when pressing the buttons, and the lack of information about how to interact with the resource. Additional observations included: including all the systems in a single application and increasing the speed, interactivity, and content of the resources. The ability to interact with each of the muscles presented was proposed in the learning resource about the muscular system.

CONCLUSIONS AND FUTURE WORK

The ratings obtained for the educational and content dimensions allow us to conclude that the educational resources evaluated to achieve the objective of supporting the learning process. However, they can be improved in the aesthetic and functional dimensions. From the comments received at the end of each evaluation, it is concluded that the user experience can be improved in future versions of the learning resources.

In the validation checks of the initial survey, it was determined that the components of the PCA show different types of populations and that there is a low correlation between the questions. Using EFA for the segment analysis, five segments related to the respondents' preferences were determined: Content and aesthetics, Functional aspects, FeedBack Guide, Educative Objectives, and Educative Learning, respectively. These results allow understanding that respondents differ in preferences and that it is necessary to maintain all aspects in the design and development of augmented reality resources to cover the entire population.

Based on the comments received in the evaluation of the learning resources, future work related to the user experience and focused on improving the aesthetic and functional dimensions is proposed. One of these is optimizing performance based on the adaptive processing of the 3D object that considers the marker's relative position. In addition, it is proposed to improve the interaction by processing inertial signals from the mobile device. The inclusion of a designer can achieve other resource improvements. Their participation would allow the improvement of the user interfaces to improve the aesthetic and functional dimensions.

The participation of the students provided the desired perspective to achieve the activity's objective. The challenge is to look for interactivity alternatives that stimulate and simultaneously include educational content with a depth appropriate to the subject's objective. The appropriation of the tools used in developing the educational resources values the feedback from the students and will allow the developers to improve them.

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