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The development of an Augmented Reality (AR) technology-based learning media in metal structure concept

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ABSTRACT: This research was motivated by the importance of developing students' abilities concerning the material representation of submicroscopic metallic structures, so that the necessary media were able to visualize metal structures by the simple, efficient and useful devices that are already available. This study aimed to describe the stages of manufacture of the technology-based learning media AR on the material metal structures, to develop students' capabilities in submicroscopic representation, and to analyze the feasibility of AR technology-based learning media on the material of metal structures. The research and development had produced products in the form of AR technology-based learning media on the concept of metal structures. The stages of the research were carried out by the analysis of metal structural concept development, design, validation, due diligence, and limited testing. Validation and limited testing were done in order to obtain feedback in the form of recommendations for the improvement and the assessment of the learning aspect, the substance of the concept, the visual communications, and the software engineering, as well as the feasibility of its use for the purpose of making the products. In general, the test results obtained $r_{calculation}$ = 0.8–1.0 feasibility and an average value of 72.5 to 88.33% was obtained at the stage of testing of a limited percentage of eligibility. It showed that the presentation of AR technology-based learning media on the concept of metal structures was feasable for use as a learning resource for students to gain the ability to develop the submicroscopic representation.

1 INTRODUCTION

Chemistry includes three levels: macroscopic, submicroscopic, and symbolic levels. The problem was that learning chemistry usually emphasized the symbolic level and problem solving only, while the visualization of both the macroscopic and submicroscopic levels were also required (Daviddowitz & Chittleborough, 2009) to make students understand the whole concept of chemistry. The metal structure was formed by the order of the same atoms tightly packed in a crystal. Atoms, molecules, and ions were theoretical models that underlaid the dynamic explanation of particle levels closely related to the representation of the submicroscopic. Learning abstract concepts and abstract concepts with concrete examples were hard to do in the laboratory, although these phenomena could be observed visually. However, animations were required for further explanation to illustrate the phenomena on a molecular basis. Research showed that many high school students, college students and even some teachers found it difficult to transfer from one level to another level of representation (Chittleborough & Treagust, 2007). In understanding chemical phenomena, both teachers and textbooks did not emphasize the differences and linkages between all three levels of representation. This was because students were considered to be able to distinguish and relate the three levels of representation (Chittleborough & Treagust, 2007). Students experienced difficulties, especially at submicroscopic and symbolic levels, because the representation was invisible and abstract while their thinking relied on sensory information. Based on these explanations, one of the alternatives that could be used to develop the three levels of representation in chemistry learning, and to help students in understanding chemistry, was using the tools to build a coherent mental representation from the material presented in the form of instructional media, such as words, pictures, and animations (Mayer, 2003). Due to the development of science and technology today and the demands of the future, computer technology was widely used in various fields, such as in the areas of information, education, business and communication, associated with educational computer technology or developed in learning. Moreover, there was a computer technology that was currently being developed, called technology-based Augmented Reality (AR) (Furht et al., 2010). The advantages of AR technology itself could be implemented widely in various media, as an application in a smartphone, in a product package, and even in the print media, such as books, magazines, or newspapers, so that it was user friendly for the low cost tools and facilities producing awesome learning media. Therefore, AR had many opportunities to develop, and could support educational facilities. In this decade, progress in the development of pedagogical concepts, applications, and technologies, the decrease of hardware costs, and the use of small-scale AR technology in educational institutions made it possible that it could be used as interesting learning media. The purpose of this research was to analyze the feasibility of AR technology-based learning media on the material of metal structures to develop the students' capabilities of submicroscopic representation (Kaufmann, 2002).

2 METHOD

The method used in this research was Research and Development (R & D). The research and development method was a research method used to produce particular products, and to test the effectiveness of these products. The subjects of this research were expert lecturers instructed to examine the feasibility of AR technology-based learning media, including experts in media education and learning, and some students of chemistry education at UIN Sunan Gunung Djati Bandung. In conducting this research, the researchers focused on the making of AR technology-based learning media. The stages of making these AR technology-based learning media refered to the CAI (Computer Assisted Instruction) tutorial design model, which had been modified. Therefore, in general, the stages of making these media consisted of the analysis phase and the design development phase, described as follows:

a. The analysis phase
b. Design development phase
c. The making visualization

3 RESULTS AND DISCUSSION

3.1 *The analysis phase*

At this stage, an analysis of the concept was conducted and the concept map of the metal structures was created based on the curriculum. It aimed to produce a material suitable with metal structure and instructional media created. The analysis results of the material concept of metal structures can be seen in Table 1 below.

After analyzing the concept, the next stage was arranging the learning indicators that would be used in the making of the AR technology-based learning media. The indicators of the metal structure learning media are presented in table. The following table visualized the indicators of metal structure learning (Table 2).

Table 1. The analysis resume of the concept of metal structures in general.

No.	Concept was analyzed	Type of concept
1	The crystal structure of solids	Abstract
2	The crystal lattice	Abstract
3	Cell unit	Abstract
4	Metallic crystals	Abstract
5	Ionic crystal	Abstract
6	Molecular crystal	Abstract
7	Covalent crystals	Abstract
8	Close-packed structure	Abstract
9	Cubical close-packed structure	Abstract
10	Hexagonal close-packed	Abstract
11	Body centered cube	Abstract
12	Face centered cube	Abstract
13	Cube	Abstract
14	Tetragonal	Abstract
15	Trigonal	Abstract
16	Hexagonal	Abstract
17	Orthorhombic	Abstract
18	Monoclinic	Abstract
19	Triclinic	Abstract

3.2 *Design development phase*

For the development of AR technology-based learning media on the metal structure studies, in any design, the development should consider the workflow design or the informational processing flow based on the flow chart and the storyboard. Moreover, after completing the analysis and the development phase, the visualization of AR technology-based learning media for metal structure studies was made. One of the instructional media visualizations can be seen in the figures below.

The learning media uses a smartphone with AR technology-based learning media for students' worksheet. While learning using these AR technology-based learning media, the students were asked to answer questions on a worksheet, in which indicators had been designed and developed, which led to the development of the students' ability with regards to submicroscopic representation in the material of metal structures.

In general, displays in this learning media consisted of: 1) home display, which was a display containing links and the identity of the material, 2) the display of learning objectives, containing learning objectives on the concept of metal structure, 3) materials display, containing the concept of

Table 2. Worksheets indicators of students learning about metal structures.

No.	Label concept	Learning indicators
1.	Solid structure	Through the crystalline structure of solids and amorphous solids, students could determine the structure of solids and amorphous solids accurately. Based on the marker containing the structure of solid crystals and amorphous solids, students could explain the differences in crystalline solids and amorphous solids. Based on the marker containing the structure of solid crystals and amorphous solids, students could accurately describe the structure of amorphous and crystalline solids.
2.	The seven basic crystal systems	Based on the marker presented, students could accurately describe the shape of the crystal lattice structure. Based on presented markers, students could accurately determine the basic parameters of the three-dimensional crystal. Based on the markers presented, students could determine the cell unit with the correct marker.
3.	Close-packed structure	Students could accurately determine the structural pattern of Hexagonal Closest Packing (HCP).
4.	The metal structure	Based on the data on the object marker, students could accurately calculate the atomic radius in nm (nanometers). Based on presented markers, students could calculate the volume of the metal crystal cell unit accurately. Based on presented markers, students could calculate the density of the metal appropriately. Based on the structure of the object marker, students could calculate the volume of the unit cell in cm^3 (cubic centimeters) accurately.

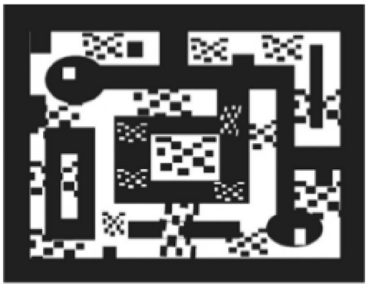

Figure 1. Example marker.

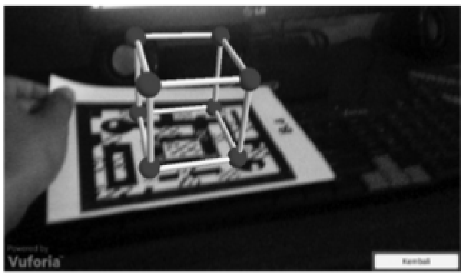

Figure 2. Example of an object on a marker.

metal structures based on learning objectives, which refered to the submicroscopic indicators, describing the material consisting of 3D-shaped crystal solids and amorphous, seven basic crystal systems, and metal structures, 4) the constituent profile page, containing information about the constituents.

The due diligence of the AR technology-based learning media was done in two stages: 1) validation test consisting of the validation test of the learning aspect, the aspects of the material substance, the aspects of visual communication, and software engineering of learning media on metal structure, 2) trial limited test of the student group, consisting of ten randomly selected students of chemistry education. The results can be seen in the table below:

The results of $r_{calculation}$ on each criterion in the learning aspects had the highest result of a feasibility value of 1.0 or was valid on the indicator of the accuracy of the use of learning strategies, so that the use of the correct learning strategies could help students to improve their comprehension and attractively and reliably present data (Arsyad, 2007). Meanwhile, the lowest result of $r_{calculation}$ was in the completeness and quality indicator of learning materials, with $r_{calculation}$ 0.8, which showed that an improvement in the quality of the materials was needed, since the quality of the teaching materials could improve the quality of the learning outcomes so that it could be well integrated (Arsyad, 2007). The result of the validity of the media stated that teaching materials were valid if the value of $r_{calculation}$ was above the value of r_{critic}, which was 0.30. Therefore, it can be concluded that the learning aspect in this research was valid and feasible to be used as a teaching material (Sugiyono, 2011).

Table 3. Results of validator expert of aspects of learning, the material substance, visual communication and software engineering.

No.	Aspect	$r_{calculation}$	Result
1.	Aspect of learning	0.90	Valid
2.	Aspects of material	0.80	Valid
3.	Aspects of visual communication	0.84	Valid
4.	Aspects of software engineering	0.95	Valid
	Average	0.87	Valid

Table 4. Average ratings of students on AR technology-based learning media.

No.	Aspect of the material content	Percentage (%)
1.	The relevance of the learning objectives	88.33
2.	The time efficiency of the use of the products	72.50
3.	Effectiveness to solve the limitations of media learning	74.16
4.	The flexibility of the media usage	80.00
5.	Media display	85.00
6.	Increase student motivation in learning	77.50
7.	The ability to encourage students to learn more	75.75
8.	Prospecting other similar media development	82.55
	Average	79.50

The result of $r_{calculation}$ on each of the criterion in the software engineering aspects, on the indicators of effectivity, efficiency, compatibility, and usability, had a value of 1.0 or was valid. It proved that the use of technology in learning not only became a tool but also delivered a learning message (Sadiman et al., 2009). Therefore, the validation of the AR technology-based learning media on the material of metal structures in the aspect of software engineering was valid.

According to the results of the stages of making the learning media, including the stages of concept analysis, indicator analysis, and design development, all three stages produced instruments in the form of flow charts and storyboards, which were used as a reference in the production of AR technology-based learning media on the material of metal structures. It showed that the storyboard was the explanation of the flow that had been designed in the form of a flow chart and used as a reference in the making process of learning media (Darmawan, 2012).

The next stage of making the AR technology-based learning media was gathering three-dimensional objects fitted with the storyboard on a metal structure material in the Google SketchUp application, after it created a marker of the media, using corel draw X.5. Furthermore, the marker was registered to vuforia developers site, so it could then be used to create an AR technology-based media that combined the unity of 3D applications so that virtual objects could be projected in real time (Roedavan, 2014).

After the AR technology-based learning media was completely made, the validation phase of the media products was done by three lecturers of chemistry education, as validation experts. This validation was conducted on the learning aspect, the aspect of material substance, visual communication aspects and aspects of software engineering. The result generally had a feasibility value (r) between 0.8–1.0, or was valid. These validation results indicated that every aspect was valid and feasible. Therefore, it can be concluded that the AR technology-based learning media on the material of metal structures on all aspects of the supporting elements of learning devices was valid and feasible for learning media.

4 CONCLUSIONS

According to the aspects of learning, conceptual substances, visual communications, and software engineering of AR technology-based learning media developed, the feasibility assessment conducted in this research resulted in a value with $r_{calculation}$ 0.8–1.0 or which had an interpretation of high feasibility, from an expert assessment or validator. This result showed that the AR technology-based learning media on the concept of metal structures was feasible to be used. In addition, the results of the feasibility test based on the responses of ten students showed good responses of 72.5 to 88.33%. Therefore, it could be concluded that AR technology-based learning media on the concept of metal structures could be used as learning tools or media.

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