Moroccan Journal of Chemistry
ISSN: 2351-812X
http://revues.imist.ma/?journal=morjchem&page=login
Maknun & al. / Mor. J. Chem. 10 N°3 (2022) 553-563
DOI: https://doi.org/10.48317/IMIST.PRSM/morjchem-v10i3.33143

Application of Interactive Multimedia in Overcoming Problem-solving Difficulties in Engineering Materials: Isomorphous Binary Phase Diagrams

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Received 30 0ct 2020,
Revised 03 Jan 2022,
Accepted 15 Jun 2022

Abstract

The objective of this study is to develop Interactive Multimedia to overcome the difficulty faced by students in problem-solving skills and calculation in the Engineering Materials course, specifically on Isomorphous Binary Phase Diagrams. The Interactive Multimedia was developed using the Design-Based Research approach and used as learning media during the Engineering Materials course's learning process. Based on preliminary research on Engineering Material course learning, 63% of students faced difficulties in learning the Phase Diagrams subject. In general, 50% had difficulties in the mastery and calculation contained in the Phase Diagrams subject. This is because the Engineering Materials course has a characteristic of abstract, complex, and dynamic concepts. The study used an experimental method with the One Group Pre-test and Post-test design. The participants in the study as a research subject were 44 students from Mechanical Engineering. The results of the study showed that Interactive Multimedia is capable to overcome the difficulties of students' in the Isomorphous Binary Phase Diagram subject. It is because interactive multimedia can attract the attention of students in the lesson material delivery, thereby increasing their interest in learning this material. It also showed that the difficulties can be overcome by the implementation of Interactive Multimedia during the learning process.

Keywords: *Engineering materials, Interactive multimedia, Isomorphous binary phase diagrams, Problem-solving skills.*

1. Introduction

Engineering Materials course is a discipline that studies the nature of materials and their application to various fields of science and engineering. This field studies the relationship between the structure of materials and their properties. Engineering materials cannot be separated from all engineering fields. This course studies the material planning, structure of materials, material properties, and capabilities of materials, both metal, and non-metal materials, as well as their application [1], [2], [3]. In the field of mechanical engineering, this course is focused on metallic materials [4].

Engineering Materials is a learning support course for advanced study. The learning process must be conveyed so that students can understand the material that has been delivered by the lecturer properly [5]. The preliminary research using the interview method was conducted on 30 students from Mechanical Engineering who had received Engineering Material courses. The results showed that the level of difficulties experienced by students during the learning process of the Engineering Materials course varied, as shown in Table 1.

Table 1. Student Difficulties Level on Engineering Materials Courses

Subject	Student	Percentage (%)
Phase Diagram	19	63 %
Shear Plane	5	17 %
Crystal Structure	6	20 %
Total	30	100 %

Based on Table 1, the most difficult subject in the Engineering Materials course is the Phase Diagram which is equal to 63%. In this subject, students learn the Phase Diagrams visualization, Phase types, Phase changes, Phase percentages, as well as Phase images on each alloy in every temperature range from liquid to room temperature [6]. Furthermore, the data shows that about 17% of students faced difficulties in learning the Shear Plane subject, and 20% of students have difficulties with the Crystal Structure subject. Problems that occur in students studying Engineering Materials with the subject of Isomorphous Binary Phase Diagrams are because of the difficulties in understanding abstract, complex, and dynamic concepts [7], this will lead to the difficulties in understanding and problem solving, as well as the delivery methods conducted by lecturers are difficult to understand by students. Problem-solving skill originates and grows from the human cognitive system, namely a process consisting of four inter-related gradual activities: identifying problems, understanding problems, solving problems, and evaluating problems [8-9]. Problem-solving is a process of finding a combination of several rules that can be applied to overcome a new situation [10]. The process is not seen as the acquisition of information that occurs in one direction from the outside into the students themselves, but as giving meaning to the students' experiences through the process of assimilation and accommodation which leads to updating their cognitive structures. Problem-solving ability is an important factor that must be mastered by students [11]. Solving a problem requires systematic problem-solving stages consisting of four stages, which are understanding the problem, making a settlement plan, implementing a resolution plan, and checking the results [12-14]. The four stages are not yet mastered by students which results in difficulties in problem-solving. Students who study Engineering Materials, especially the subject of phase diagrams should be able to master the material easily, but in reality, they have difficulties in mastering the phase diagram subject. It can be seen from the initial research data, that the percentage of students who master the essential material is very small, most of the students experienced difficulties with calculating the percentage of phase diagrams and the average test score is 73. It was also shown by a related study conducted on 26 students, that the use of animation media showed an increase in learning outcomes [15]. When pre-test, the average test score is 10.32, and after the post-test, the average test score increased to 83.20, compared who did not use the animation media with 7.89 average pre-test scores and 64.27 average post-test scores.

Based on previous research, learning outcomes after using multimedia animation have not been optimal. Some factors that lead to learning outcomes that are not optimal in previous studies include:

(i) The media presented are not optimal

(ii) There is no variation in the example of calculation problems in the media.

(iii) The unavailability of evaluation facilities in the media so that students can measure their knowledge by grades.

(iv) Students do not operate media independently.

(v) The voices in the media are not clear.

(vi) The objective of the study is to produce Interactive Multimedia to overcome the difficulties faced by students in problem-solving skills and calculation on Isomorphous Binary Phase Diagrams subject, as well as analyze the impact of Interactive Multimedia in the learning process of Engineering Materials and its impact on increasing the Problem-solving competency of the students. The interactive multimedia was developed using the Design-Based Research (DBR) approach and used as learning media used by the lecturer in the Engineering Materials course.

Multimedia can combine various types of media, such as images and interactive audio-video [16-19]. It can improve holistic competency development [20]. Furthermore, with multimedia lecturers can integrate text, graphics, animation, and other media into one package to present comprehensive information. The use of multimedia technology in learning can make students more active and motivated during the learning process [21].

Through this study, improvements and innovations in the media used in the learning process are carried out. Some novelties in the Interactive Multimedia developed include:

(i) Deepening in the discussion of isomorphous binary phase diagram calculations,

(ii) Giving examples of varied calculation problems,

(iii) Providing an evaluation menu so students can measure their knowledge, and

(iv) Bringing voice improvement in the explanation of the material.

Innovations carried out can help students become actively involved and improve student learning outcomes [22]. The application of educational technology has created a modern learning paradigm whose core elements combine the basic concepts of pedagogy and anthropology to discover new learning processes [23].

1.1. Isomorphous binary phase diagrams

The isomorphous binary phase diagram is one of four types of phase diagrams, which are two elements that are completely soluble in liquid or solid-state. The example of the isomorphous binary phase diagram is shown in Figure 1. A lot of information about controlling the microstructure of certain metal alloys is easier if it is drawn in the form of diagrams, namely phase diagrams or equilibrium diagrams. Many changes in the microstructure occur during phase transformations, namely changes that occur between two or more phases because of the temperature changes. The indicator can be a transition from one phase to another or the formation of a new phase or the loss of a phase. The phase equilibrium diagram illustrates the relationship between temperature and the composition and quantity of the phases at equilibrium. According to Figure 1, some information about the Cu-Ni alloy includes:

(i) *Y-axis*: temperature.

(ii) *X-axis*: alloy composition (in % weight – bottom, in % atom – top).

(iii) *α region*: solid soluble substitution consisting of copper-nickel having an FCC crystal structure.

(iv) *L region*: the area when the alloy is completely dissolved in the liquid state.

(v) *α + L (solid+liquid)*: the area where the alloy is completely in a liquid and solid state.

(vi) *Liquidus line*: a line that shows the lowest temperature at which the metal is in a molten state or the

temperature at which the initial solidification occurs from the molten state due to the cooling process.

(vii) *Solid line*: the line that shows the highest temperature when the metal is solid.

In the Binary Phase Diagram system, if the composition and equilibrium temperature is known, three pieces of information can be obtained, namely:

(i) Alloy phase

(ii) Phase composition

(iii) Percentage or phase fraction.

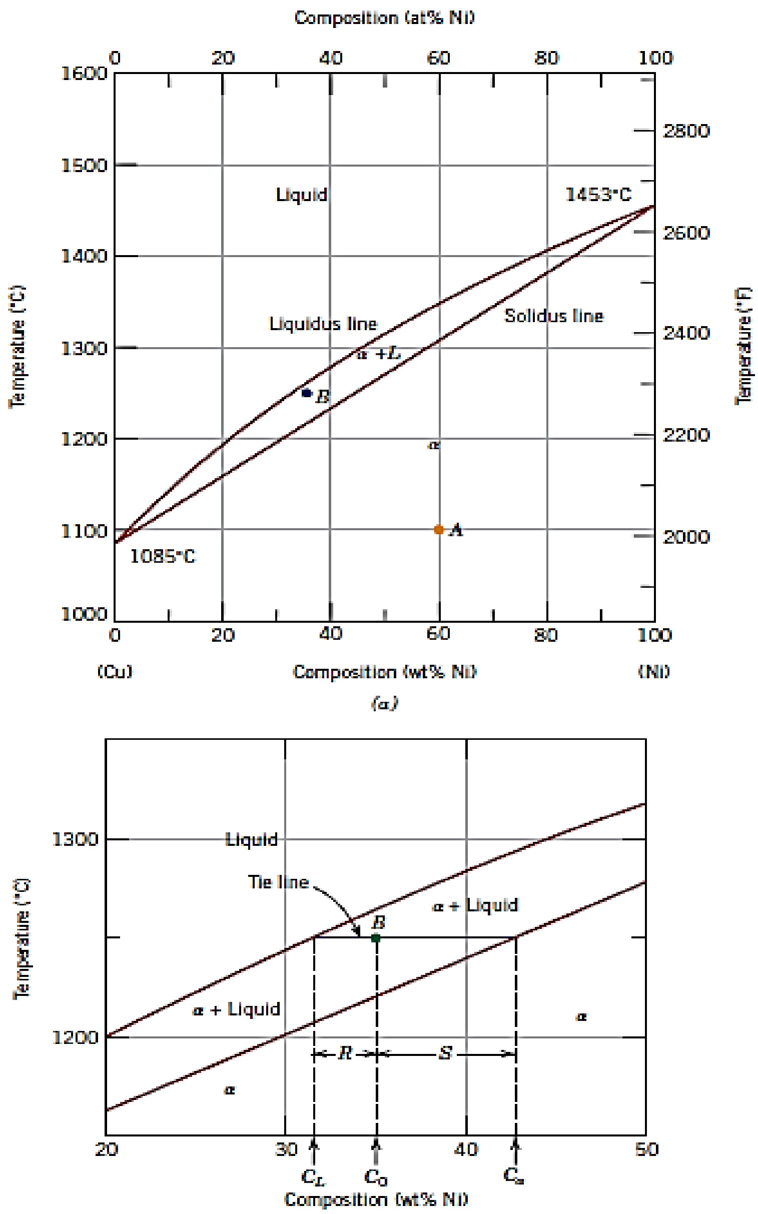

Figure 1. (a) Isomorphous binary phase diagram Cu-Ni Alloy, (b) Cu-Ni phase diagram with B composition. (Adopted from William D. Cllister, Jr. 2007).

2. Materials and methods

The development of Interactive Multimedia used a Design-based Research (DBR) with the Reeves method. The Reeves method [24] contains 4 stages:

(i) Collaborative analysis of practical problems by researchers and practitioners.

(ii) Solution development by existing design principles and technological innovation.
(iii) A repeated cycle of testing and refinement of solutions through practice.
(iv) Reflections to produce design principles and improve the implementation of solutions.

During the Interactive Multimedia development, the assessment of the Interactive Multimedia feasibility was conducted by Material experts and Media experts. The process aims to identify weaknesses in multimedia with indicators that have been prepared so that improvements can be made to find assessment results suitable for use as learning media. During this process, Material Experts and Media Experts fill out the questionnaire using a rating scale as in Table 2.

Table 2. Rating Scale Guide

Score	Explanation
0	Strongly Disagree
1	Disagree
2	Neutral
3	Agree
4	Strongly Agree

The improvement of students' problem-solving ability was measured using a pre-experimental method with a *one-group pre-test and post-test design*. In this design, a population or sample was given a pre-test to find initial conditions, which are then processed through interactive multimedia learning. In the final stage, the samples are given a post-test to see the improvement. The research design used in this study can be seen in Figure 2.

O_1	X	O_2

Figure 2. One group Pre-test and post-test design. (O1 = Pre-test activity. X = Treatment activity [Interactive Multimedia implementation]. O2 = Post-test activity).

The subjects of this study were Mechanical Engineering Education (DPTM) students enrolled in an Engineering Materials course. The research sample used was the 2018 class of DPTM students, a total of 44, using a simple random sampling technique. The analysis of the validation results data aims to determine the percentage level of interactive multimedia as a learning medium. The ideal score should be determined first [25]. An ideal score is a set of scores assuming that each respondent to each question gave the highest-scoring answer.

The formula to analyze the validation data is shown as follows:

$$Percentage = \frac{Actual\ Score}{Ideal\ Score} x\ 100\% \qquad (1)$$

In this study, the N-Gain analysis was used to measure the student outcome improvement after using Interactive Multimedia in the learning process. The formula used for the N-Gain analysis [26] is as follows:

$$\langle g \rangle = \frac{T_2 - T_1}{Sm - T_1} \qquad (2)$$

where <*g*> is the Normalized Gain, T_1 is the Pre-test Score, T_2 is the Post-test Score, and S_m is the Maximum Score.

3. Results and Discussion

Interactive Multimedia of Isomorphous Binary Phase Diagram is developed based on a storyboard that has been compiled and based on the Engineering Materials textbook [27]. The main software to develop it is Adobe Flash CS3 Professional which functions to process images, sounds, and videos. The video in question is a video that has been given a command/coding using *Actionscript 2.0* in *Adobe Flash CS3 Professional*. Other supporting tools are *Adobe Photoshop CS3* and *Corel Draw X4* to create background images and buttons used in navigation in interactive

multimedia. *Adobe Audition CS6* to improve the quality of sound produced after the recording process, and swivel to produce animated videos.

In this study, interactive multimedia is a tool to deliver learning material for the Isomorphous Binary Phase Diagram subject, especially in the discussion of problem-solving or calculation. Interactive multimedia has been designed based on the objectives so that it can overcome the difficulties of problem-solving faced by students.

This Interactive Multimedia program guides students in systematic problem-solving. In addition to displaying dynamic images, Interactive Multimedia also has the characteristics of interaction between multimedia and students, as shown in Figure 3.

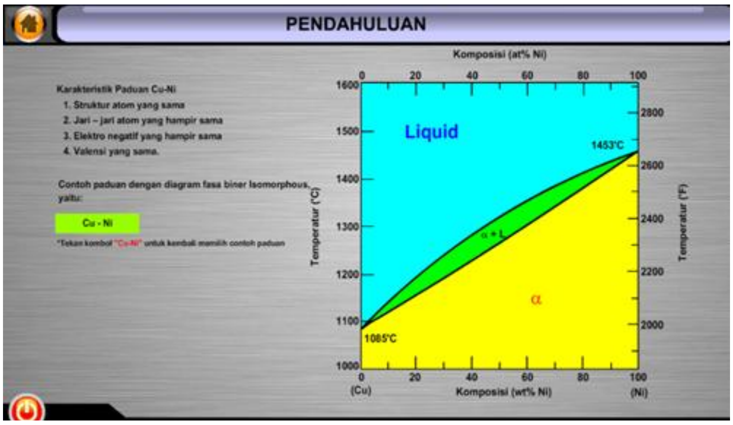

Figure 3. Interactive multimedia of isomorphous binary phase diagram.

Interactive Multimedia products that have been developed are then assessed by Material and Media Experts to determine their feasibility. The results obtained based on Expert testing of Materials obtained one component which gets a percentage of 93.3%, namely the relevance component of the material caused by the material has not been equipped with an explanation of the characteristics of the various alloys including Isomorphous Binary Phase Diagrams, and the material delivered is limited to mentioning the Alloy which includes the Isomorphous Binary Phase Diagram. The average value obtained from testing by material experts is 95.14% which shows that the material to be presented is very feasible to use.

The results obtained from Media experts indicate that Interactive Multimedia products are feasible to be used after improvement by obtaining an average percentage rating of 75.04%. The smallest component value is the device compatibility component, which is equal to 50% caused by multimedia which can only be used only on computer devices. For other components, the percentage is quite satisfying.

Based on the judgment results from material experts and media experts obtained an average percentage assessment of 85.09%. The average value is included in the classification which is very feasible to use, as shown in Table 3.

Table 3. Interactive Multimedia Judgment Result

Judgment	Average Result (%)
Material Expert	95.14
Media Expert	75.04
Average	85.09

After the Interactive Multimedia is developed and assessed, then applied to the learning process of the Isomorphous Binary Phase Diagram subject. The first thing to do is to do a Pre-test for the sample (participants). The pre-test aims to obtain preliminary research data on students about Isomorphous Binary Phase Diagrams. The pretest is provided

using instruments that have been validated by experts. The instrument consisted of 2 essay questions with 44 students taking the pretest and working in 30 minutes. The highest value obtained is 16.67 and the lowest is 0 with an average of 1.86. Based on the results, the average value is below the graduation standard, according to the UPI Education Implementation Guidelines 2018, if the value is less than 55 then declared to be a failure. These results can occur due to the lack of basic knowledge of students regarding the Isomorphous Binary Phase Diagram.

The Post-test activity is carried out after students have finished implementing the learning process using interactive multimedia. The instrument given is the same as the instrument for the pretest. Students are given 30 minutes to complete the questions given. The highest value obtained from the Post-test is 100 and the lowest value is 8.33, with an average value of 82.77, as shown in Figure 4.

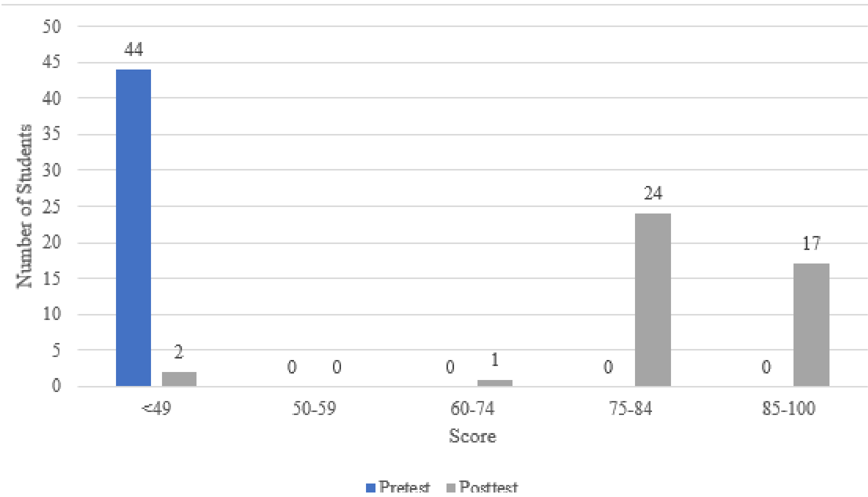

Figure 4. Pretest and posttest results

The results indicate that there is an influence on problem-solving skills in students after being given learning using interactive multimedia. It can be proven by the N-Gain data which shows an average value of 0.82 where the value is directly proportional to the N-Gain component of the questions that get an average of 0.82, which shows that the results are included in the high category, as shown in Figure 5.

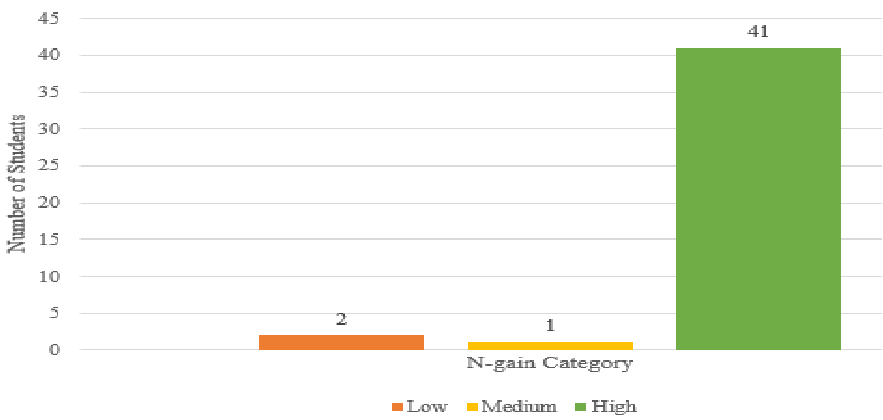

Figure 5. Recapitulation of n-gain category distribution.

Based on the Recapitulation of the N-Gain score (Figure 5), 41 students get an improvement in the high category, although there are students who get an improvement in the medium category by one person and a low category by two people. This is inseparable from the characteristics of interactive multimedia itself.

Interactive multimedia is included in the combination media from a combination of print, audio-visual, and computer technology [28-29]. Interactive multimedia displays a combination of static images and animation such as dynamic text, images or visuals, and audio, and they are all controlled using a computer, so the learning process involves many sensory devices and involves long-term memory [30-31]. The more sensory devices used in the process of receiving and processing information, the more likely the information is understood and retained in memory [28]. Other characteristics possessed by this interactive multimedia are in addition to displaying the effect of animated motion but also providing the side of interaction that is built between multimedia and its users so that it can be more interesting to students and easy to teach. The multimedia can attract the attention of students in the lesson material delivery, thereby increasing their interest in learning this material. Their skills are automatically increased due to their strong curiosity and multimedia also leads them to know the steps systematically. With the effect of moving animation, the way the material is delivered by the narrator and the terms of the interaction built between multimedia and its users are more interesting and easier to understand by students. The results of related studies were in line with the results of this study. The results of the effectiveness of the media in large student group trials gained mastery learning reaching 80%, categorized as "effective" [32]. There is another similar study concerned with the development of Interactive Multimedia-based learning media to facilitate students in the Mathematics course, concluding that there is a positive impact of interactive multimedia implementation in mathematics courses [33]. The implementation of Interactive Multimedia is proven to improve generic science skills and scientific literacy [34], as well as improve the ability to read projected images of vocational students [35], and also can improve learning outcomes of vocational high school students' competencies such as in automotive industry management and electrical wiring subject [36-37]. Based on the discussion, it can give an idea that interactive multimedia can solve problems in the learning process of the Isomorphous Binary Phase Diagram subject, especially for problem skill and calculation aspects. Isomorphous Binary Phase Diagram is a subject that discusses abstract and microscopic matters so that it is likely not to be visualized by students. These problems can be overcome by the application of interactive multimedia. A media is needed that can manipulate the theoretical model into a realistic model to be more interesting to students and easily understood so that students can imagine in real form, and lead to be able to analyze, plan solutions, implement solutions, and re-examine the results of problem-solving. The learning process by integrating digital technology affects the student’s learning outcome and skills development [38-47] In this case, students' problem-solving skills improved [48-49].

Conclusion

Based on the analysis and discussion of the research, it can be concluded that the Interactive Multimedia is feasible to use as a learning media for Engineering Materials course, especially for Isomorphous Binary Phase Diagrams subject, with the average of judgment results in a very feasible category. Students’ improvement in problem-solving competency showed an increase based on the N-Gain analysis in the high category. Based on the testing data, in overcoming the problem-solving skills of students, it was found that there was an increase in learning outcomes. It also shows that the difficulties of solving problems in students can be overcome by the implementation of Interactive Multimedia in the learning process.

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