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PAPER

POGIL Learning Model—Metaphorming for Mobile-Based Cryptography Creation

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ABSTRACT

The cryptography course has a mathematical basis and involves programming algorithms in the creation process while the implementation utilizes a programming language. Cryptography has been widely implemented in everyday life. However, the interest and learning outcomes of students in cryptography courses have not met expectations. Process-oriented guided inquiry learning (POGIL) models integrated with metaphor. The POGIL metaphorming model is a student-centered learning model directed at active and creative thinking processes. One of the important processes in this stage is to develop a preliminary form of the product, conduct preliminary field testing, make the main product revision, conduct the main field testing, and perform operational product revisions. Based on the findings from the initial stage, an integrated learning model was developed for the cryptography course. Data for the model validation stage included model books, textbooks, lecturer's guides, and student guides, calculated using content and construct validation techniques. Analysis of validity test data involves calculating the average score of all validator answers using Aiken's coefficient v. The study results indicated that the model learning POGIL metaphorming is validly designed to enhance student learning processes and outcomes in cryptography courses.

KEYWORDS

process oriented guided inquiry learning (POGIL), learning model, metaphorming, cryptography

1 INTRODUCTION

21st-century competencies necessitate that the education sector integrate knowledge, skills, attitudes, and expertise in information and communication technology to prepare graduates who can effectively tackle global challenges [1]. Therefore, courses are needed that can support 21st-century skills. One of these courses is cryptography. Cryptography is the science of encoding and securing messages when they are transmitted from one place to another [2]. Cryptography courses have a mathematical basis and involve programming algorithms in the creation process, while the

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implementation utilizes a programming language [3]. Cryptography has been widely implemented in everyday life, such as in credit cards, barcoded goods, and passwords used in digital communications such as email and Facebook. The APTIKOM KKNI document states that students must be able to achieve the learning objectives, which include designing a security system and implementing ongoing adjustments to maintain the current configuration. However, up to now, the interest and learning outcomes of students in cryptography courses have not met expectations. One of the problems faced is teaching methods and the learning environment. The complexity of the material in the cryptography course, along with its relationship to other subjects, makes it challenging for students to comprehend. Therefore, a thorough understanding of the theory is necessary to overcome this difficulty. This can reduce students' skills when studying cryptography [4]. Apart from that, some students experience difficulties in learning cryptography because they do not have sufficient prerequisite skills and are unable to implement the concepts using their skills [5]. According to research, teaching models and methods are one of the causes. Apart from that, conventional models with traditional approaches are also considered ineffective in teaching cryptography [6]. Based on initial observations, it is known that cryptography learning still relies on traditional models using PowerPoint presentations. Learning is not yet fully student-centered, resulting in low levels of student learning and innovation in cryptography courses. Apart from that, students are also less interested in cryptography courses. Awareness of the importance of cryptography in this age of information technology is still low. It can be seen that not all students take cryptography courses.

Various efforts have been made to overcome this problem, one of which is updating the learning model (Tan, Atan, and Kadir, 2020). In this case, the POGIL model (process oriented guided inquiry learning) is integrated with metaphorming. POGIL will be used as a student-centered learning model directed at active and creative thinking processes [7]. The choice of this model is also based on previous research. The POGIL model can develop critical thinking and problem-solving skills, while the metaphorming model can increase creativity, leading to innovation. The integration of these two models aims to develop students' learning abilities and foster innovation. This research aims to test the validity and feasibility of developing the POGIL-metaphorming model for use in cryptography courses.

2 LITERATURE REVIEW

Development is an effort made to modify an existing model or product by adding to or enhancing its functionality [8]. Development must be carried out by paying attention step by step, sequentially according to the stages of the models used [9]. In simple terms, a model is defined as a concept or idea that is used to explain something [10]. Meanwhile, learning is an educational activity that involves interactions between students and lecturers. For the learning atmosphere to be conducive to learning activities, there must be a two-way interaction between students and lecturers [11]. A learning model is a framework used to guide learning planning in class or tutorials, as well as to determine learning components such as books, computers, films, and curriculum [12].

The POGIL learning model is a developmental approach that combines POGIL is a student-centered learning approach that emphasizes teamwork. In this model, the lecturer acts as a facilitator while students independently learn to grasp concepts by drawing on their knowledge and previous experiences. This process follows a learning cycle consisting of orientation, exploration, concept discovery (concept formation), application, and performance assessment (closure) [13]. The POGIL-metaphorming model is based on the philosophy of vocational education, which aims to prepare students to enter the workforce by developing 21st-century skill competencies [14]. Students must have 21st-century skills competencies, which include (1) critical thinking and problem-solving; (2) communication; (3) collaboration; and (4) creativity and innovation [15]. This is an application of the POGIL-metaphorming model that aims to: a) improve process skills in the areas of study (learning), thinking, and troubleshooting (problem-solving) [16], b) increase students' activeness in participating in learning [17], c) build relationships between fellow students and between teachers and students [18], d) connect learning with information technology, e) improve communication and group skills, and e) increase creativity to create new ideas for solving problems [19]. This is also in line with the educational philosophies of essentialism, pragmatism, and pragmatic reconstructionism. Constructivist learning theorists believe that knowledge acquisition is based on active involvement in the learning process. According to constructivist learning theory, the results of knowledge obtained in the learning process are a combination of new knowledge and previous experience. A person is said to be engaged in a learning process when they can generate new knowledge by offering fresh interpretations of the social, cultural, physical, and intellectual environment in which they reside. Through digital learning and creative thinking, students can construct knowledge within the framework of constructivist learning [20].

The metaphorical model of learning involves understanding how genius individuals think, particularly in terms of connecting seemingly unrelated subjects in a way that [21]. There are four steps in metaphor, namely: connection, discovery, invention, and application [22]. Mobile technology is fascinating for various applications, such as rescue operations, environmental monitoring, tactical operations, and more, as it enables human communication without relying on permanent infrastructure. However, this flexibility creates additional security vulnerabilities [23]. The POGIL metaphorming model is based on constructivist theory. The learning activities in this model are student-centered [24], emphasizing searching for and finding answers to the problems posed through critical and analytical thinking processes. Next, solve the problem by generating innovative ideas. Learning theory, connectivism, or distributed learning should be considered an updated version of constructivism, understood as a general philosophy of education for the digital era [25]. Connectivism provides insight into the skills and learning tasks students need to thrive in the digital era [26]. POGIL-metaphorming learning adopted information processing theory. The learning process is research-based, involving collecting as much information as possible, identifying it, connecting it with previous understanding, processing the information, and drawing conclusions. Based on these explanations, it is concluded that POGIL metaphorming is grounded in the learning theories of constructivism, cognitivism, connectivism, and information processing. Cryptography is the art of encoding messages. The message is encrypted before being sent to ensure secure delivery to the recipient [5]. Cryptography is an important tool for securing information transmitted by computers [27].

If someone steals the message, that person must decrypt it first because, during the message transmission, it is in the form of a password. Cryptography has been widely used in the digital world and is a crucial component of information and telecommunications, encompassing almost all networks, particularly the Internet [4]. Cryptography has been widely used in daily activities, such as securing ATM passwords and emails. It is the science of creating secret codes and plays a significant role in the advancement of computer technology. Cryptography is fundamental for comprehending information security in relation to computer use. Cryptography is the art of maintaining message security. The art of transforming the original message into incomprehensible codes is to prevent unauthorized parties from understanding it [6]. Cryptography involves the analysis and design of mathematical techniques to secure communications from potential threats [5], [45]. Based on several descriptions, it can be concluded that cryptography is the art of creating secret codes using fundamental mathematical principles for security purposes. Cryptography can be implemented using programming languages. Some good programming languages used in cryptography are Python, Go, Ruby, C++, C#, Java, and PHP.

3 METHOD

The design used to develop the product follows the Borg and Gall development stages. One of the important processes in this stage is developing a preliminary form of the product, conducting preliminary field testing, making main product revisions, conducting main field testing, and finalizing the operational product. Based on the findings in the initial stage, an integrated learning model was prepared for the cryptography course, incorporating competency standards for learning skills and innovation. The activity at this stage is to prepare an initial design (draft) of the model. This is based on preliminary studies, philosophical foundations, learning theories, model development theory, and the feasibility of implementation. This activity produces products such as model books, student and lecturer guidebooks, teaching materials, and evaluation tools. After the products are produced, the next step is to assess the feasibility of the resulting draft by conducting trials with experts and testing the viability of the basic concepts and theories employed. The results received are validated by experts. Based on the validation results and expert suggestions, improvements were made to the draft model and several instruments. The instrument used to assess validity was developed based on assessment aspects with indicators.

Table 1. Indicators for validation of development results

Variable	Assessment Indicators	Number of Validity Question Items
Model book	Writing Format	6
	Language usage	3
	Model Rationalization	3
	Model Supporting Theory	6
	Model Characteristic	3
	Instructional and accompanying impacts	5
Syntax	Orientation	8
	Exploration	3
	Concept Formation	4
	Creation	2
	Application	2
	Closing	2
Lecturer's guidebook	Writing Format	6
	Language Usage	3
	Introduction	6
	Content Aspect	15
	Evaluation System	5

(Continued)

Table 1. Indicators for validation of development results *(Continued)*

Variable	Assessment Indicators	Number of Validity Question Items
Student's guidebook	Writing Format	6
	Language Usage	3
	Introduction	6
	Content Aspect	15
	Evaluation System	7

Content validity is the conclusions and performance measured based on the material being discussed and tested. Referring to research on the development of an entrepreneurship training model which has assessment items for a learning model consisting of assessing the completeness of model books, student books, syntax and teacher books [28]. It is said to have content validity, also known as content validation, if the model development is based on rationality theorists. Pun theory is clearly explained as the philosophical, social, and conceptual frameworks are elaborated upon in the development of a coherent model. During the model validation stage, data includes model books, textbooks, lectures, and student guidebooks, which are assessed using content and construct validation testing techniques. Analysis of validity test data involves calculating the average score of all validator answers using Aiken's coefficient. Aiken's formula for calculating the content validity coefficient is based on expert judgment regarding items that represent the construct being measured [29]. This research involves the use of five experts as assessors for expert validation to evaluate the feasibility of the product. The panel includes two experts in vocational education and learning models, two technology experts, and one cryptography expert.

4 RESULTS

4.1 Research rationalization

The rapid development of information technology in the 21st century necessitates that students possess abilities, knowledge, and skills in the areas of media, technology, information, learning, innovation, as well as life and career skills [30]. To compete effectively in the 21st century, as started by Trilling and Fadel [31], one must master learning and innovation skills. Students must learn to think creatively, plan systematically, analyze critically, work collaboratively, communicate clearly, design iteratively, and learn continuously [32]. However, the lack of interest and low learning outcomes in cryptography related to student learning skills and innovation require a new paradigm for enhancing educational outcomes. It is necessary to enhance the quality of learning by seeking effective learning techniques or methods that align with the values of soft skills, ensuring that the success achieved is balanced across the cognitive, affective, and psychomotor domains [33]. Problem-solving is offered to develop an integrated POGIL metaphoric model. The learning concept implemented aims to stimulate brain function, enabling individuals to think critically and creatively to solve a variety of problems through innovation. In the implementation of the POGIL learning process, metaphor focuses on students working in teams of 3–4 people, where each person has their own role and duties. These roles include manager or group leader, spokesperson, note-taker, and evaluator. Every task role will be different but connected. And every person's role will change at each meeting. Learning is research-based and built upon prior knowledge or real-life experiences.

Apart from that, students are encouraged to explore and innovate. The results of the discovery or creation are then presented. Furthermore, the results of the discovery and/or creation will be used to solve the given problem or task. The expected achievement is to develop an effective learning model to equip students with learning and innovation skills, including critical thinking and problem-solving, creativity and innovation, and communication and collaboration [31].

The Pogil learning model – This metaphor has been proven to be valid and can improve students' abilities in creating Mobile-Based Cryptography. This learning model is effective and is recommended to be used for appropriate learning.

4.2 Syntax model

The POGIL-metaphorming model was developed by integrating POGIL syntax with metaphorming. Developed to adapt to learning needs based on 21st-century skills, students must have competencies including: 1) critical thinking and problem-solving skills; 2) communication; 3) collaboration; and 4) creative thinking and innovation skills [32], [34]. This aligns with the core subjects of 21st-century education outlined by the Research and Development Agency of the Ministry of Education and Culture in Indonesia in 2013. These subjects include learning and innovation skills, proficiency in utilizing technology and information media, and the ability to work and thrive with essential life skills. Development must be adapted to the philosophical foundations of vocational education and learning theory [35], [36].

The POGIL model is a learning model oriented towards constructivist theory [37]. Where students learn to apply their knowledge and experience to comprehend and construct a concept. Activities in this learning model focus on a series of processes aimed at finding solutions to the problems in question through critical and analytical thinking. The POGIL learning model is student-centered and process-oriented to enhance students' skills [38]. Meanwhile, the process is based on a learning cycle that includes exploration, concept formation, and application [19], as well as evaluating students in each learning session. POGIL model integration-metaphorming was carried out, as shown in Table 2 below:

Table 2. Integrasi sintak POGIL-metaphorming

No.	POGIL	Metaphorming	POGIL-Metaphorming
1.	Orientation	Connection	Orientation
2.	Exploration	Discovery	Exploration
3.	Concept formation	Invention	Concept formation
4.	Application	Application	Invention
5.	Closure		Application
6.			Closure

Table 2 illustrates the structure of the POGIL-Metaphorming model, which includes orientation, exploration, concept formation, creation, and closing. Orientation is the initial step in preparing for learning. It involves explaining the learning process, techniques, and methods that will be used. It aims to motivate students, spark their interest and curiosity in the material to be discussed, and convey course descriptions, learning objectives, and outcomes. Additionally, it provides general knowledge about the material, connects to prior knowledge, and stimulates problem-solving by integrating existing knowledge. Form small groups of students to collaborate on their respective tasks and roles. These roles and duties include:

a) The manager actively participates, distributes work and responsibilities, resolves problems if disputes arise, and ensures that all members participate and understand.
b) The spokesperson, actively participates, provides views and conclusions on behalf of the group, and conveys the results of group discussions in front of the class.
c) The recorder actively participates and prepares written final reports and other documentation for group discussions.
d) The strategy analyst or reflector actively participates by reflecting on what has and has not been understood during discussion activities, as well as identifying areas for improvement in group discussions.

A model framework is principally formed from rationalization based on theory and previous research results. To explain further how learning theories are structured to support the formation of the framework and principles of the POGIL Syntax Metaphor Model, see Table 3.

Table 3. Learning theories supporting POGIL model syntax-metaphorming

Syntax	Learning Theory
Phase 1 Orientation	**1.** A lecturer is tasked with creating a learning environment (*scenario of problems*) by demonstrating learning experiences that are authentic or real and can be applied to the learning process. **2.** In the learning process attention is needed (*directing attention*). **3.** *Advance Organizers*. Student orientation on the material to be discussed helps students' readiness to gain new knowledge and improve understanding. **4.** Usage *Advance Organizers* can activate prior *knowledge* of students before entering learning.
Phase 2 Exploration	**1.** Discussion forums fall into the field of connectivism because they create networks and connections between students and instructors. **2.** Connectivism theory suggests that cognitive tasks between humans and technology occur in networks, which are connections between individuals, groups, systems, fields, ideas, or communities. **3.** According to Brunner, cognitive development occurs in three stages, namely: *enactive*, students research because they directly experience a reality; *iconic*, students see the world through pictures or verbal visualization and the third stage symbolic where the students have abstract ideas that are heavily influenced by language as well as logic and communication are implemented with the help of the symbol system. **4.** Constructivism relies on the use of prior knowledge in the construction of new meaning, previously constructed knowledge structures are taken and used as separate packages for the development of new knowledge structures. **5.** Constructivism emphasizes the importance of: (1) Individual knowledge construction; (2) Individual responsibility and effort and discovery of information; (3) Individual differences in learning styles and strategies; (4) Active and creative role of students; (5) Meaningfulness and learning objectives; and (6) Cooperative work and interaction for effective learning.
Phase 3 Concept Formation	**1.** Jean Piaget's Cognitive Theory, in the environment of developmental psychology gives many main concepts that will influence the development of the concept of intelligence. **2.** The cognitive theory of learning states that students construct and revise mental models of concepts using active, iconic, and symbolic representations of concepts to develop deeper conceptual understanding. **3.** *Constructivism* is a process in which students can build a new concept with construct own knowledge, both from current and previous knowledge. *Constructivism* relies on the use of prior knowledge in the construction of new meaning, previously constructed knowledge structures are retrieved and used as separate packages for the development of new knowledge structures. **4.** Individuals learn by investigating, creating structures, actively seeking an understanding of a concept, and integrating and modifying new constructions into knowledge so that the meaning of learning is thinking, acting, and feeling [39].
Phase 4 Creation	Constructivist learning theory. Individuals not only learn to do things but also create them [40].
Phase 5 Application	Connectivism predicts that the learner's role is not to remember or understand all the abundant knowledge, but rather to have the capacity to discover and apply knowledge whenever needed.
Phase 6 Closing	In cognitive learning theory, the process is the main thing compared to the learning outcomes.

4.3 Model validation analysis

Validity analysis is conducted after undergoing a product revision process, relying on expert opinion. The assessment is carried out after the product has been developed through a revision process based on input from experts during the discussion group forum. The following are the results of product validation analysis by experts:

1. Validation of product validity and practicality instrument assessment: The results of processing the values obtained from experts on the instrument's validity and practicality are shown in Table 4.

Table 4. Product validity and practicality instrument validation results

No.	Assessment Aspects	Aiken V Score	Interpretation
1	Feasibility of instrument content	0.86	Very valid
2	Feasibility of validity instrument language	0.84	Very valid
3	Qualifying aspects graphics	0.83	Very valid
	Average value	0.84	Very valid

Table 4 shows that the content validation instrument obtained a score of 0.86, the language score for instrument validation was 0.84, and the graphics aspects obtained a score of 0.83. Therefore, the average value obtained was 0.84. In this way, the validation instrument is a representative construction that will be measured and is considered suitable for assessing other products.

2. Model book validation: The values obtained from experts are then processed to determine the validity of the product. The results of value processing are shown in Table 5.

Table 5. Model book validation results

No.	Assessment Aspects	Aiken V Score	Interpretation
1	Writing format	0.88	Very valid
2	Language usage	0.70	Valid
3	Model rationalization	0.84	Very valid
4	Theories supporting model creation	0.82	Very valid
5	Model characteristics	0.87	Very valid
6	Model Syntax	0.85	Very valid
7	Social system	0.83	Very valid
8	Reaction principle	0.82	Very valid
9	Support system	0.84	Very valid
10	Instructional and accompanying impacts	0.84	Very valid
	Average value	0.83	Very valid

Table 5 shows that the overall score obtained has a valid interpretation and a high rating with an average value of 0.83. The symptoms for specific components are as follows: writing format 0.88; rational model 0.85; supporting theory model

0.82; model characteristics 0.82; model syntax 0.85; social system 0.83; reaction principle 0.82; support system 0.84; instructional and accompanying impact 0.84. However, the use of language scored 0.70, which is considered high. Next, the POGIL model of metaphor is deemed feasible to implement during the model validation stage.

3. Validation of the lecturer's guidebook: The next assessment involves the lecturer's guidebook. The results of the assessment conducted by experts in the FGD are then processed, and the processed results are presented in Table 6.

Table 6. Validation results of lecturer's guidebook

No.	Assessment Aspects	Aiken V score	Interpretation
1	Writing format	0.87	Very valid
2	Language usage	0.81	Very valid
3	Introduction	0.83	Very valid
4	Content aspects	0.82	Very valid
	Average value	0.83	Very valid

It can be seen in Table 6 that all aspects of the assessment have a highly valid interpretation, with an average of 0.83 and a very strong correlation. The assessment aspects consist of writing format (0.87), language use (0.81), preliminary (0.83), content aspect (0.82), and evaluation system (0.82). Furthermore, the lecturer's guidebook was deemed suitable for implementation during the model validation stage.

4. Validation of student's guidebook: Apart from the lecturer's guidebook, an assessment was also conducted on the student's guidebook. The results of the assessment conducted by experts in the FGD have been processed and can be viewed in Table 7.

Table 7. Validation results of student guidebook

No.	Assessment Aspects	Aiken V Score	Interpretation
1	Writing format	0.83	Very valid
2	Language usage	0.82	Very valid
3	Introduction	0.81	Very valid
4	Content Aspects	0.80	Very valid
5	Evaluation system	0.81	Very valid
	Average value	0.81	Very valid

Table 7 demonstrates that all aspects of the assessment have a highly valid interpretation, with a mean of 0.81 and a very strong correlation. The assessment aspects consist of writing format (0.83), language use (0.82), preliminary (0.81), content aspect (0.80), and evaluation system (0.81). Furthermore, the student guidebook was deemed suitable during implementation at the model validation stage.

5. Textbook validation: Lastly, the assessment of textbooks has been completed by experts in the FGD, and the results have been processed, as presented in Table 8.

Table 8. Textbook validation results

No.	Assessment Aspects	Aiken V Score	Interpretation
1	Self-instruction	0.84	Very valid
2	Self-contained	0.83	Very valid
3	Stand-alone	0.90	Very valid
4	Adaptive	0.85	Very valid
5	Friendly	0.85	Very valid
6	Graphics	0.85	Very valid
7	Language	0.83	Very valid
8	Evaluation system	0.85	Very valid
	Average Value	0.85	Very valid

Table 8 demonstrates that all aspects of the assessment have highly valid interpretations. The assessment aspects consist of self-instruction (0.84), self-contained (0.83), stand-alone (0.90), adaptive (0.85), user-friendly (0.85), graphical aspect (0.85), language aspect (0.83), and evaluation system (0.85). Based on the assessment indicator value for each item, an average of 0.85 was obtained, indicating a very high score. In this case, the textbook is deemed suitable for implementation during the model validation stage.

5 DISCUSSION

The development of technology and information in the 21st century requires a workforce that can make breakthroughs in thinking and action to tackle various new challenges [41]. This allows educational institutions to make changes to respond to current developments [42]. Education must utilize digital media and technology, and learning activities need to be adapted to meet the demand for knowledge [43]. Learning materials need to be designed authentically so that students can collaborate to provide solutions for solving learning problems using available information [44]. So, a learning innovation is needed—one that prioritizes the process over the results. Where the learning process is oriented towards student activities so that it can develop students' abilities in thinking, communicating, and collaborating. The adaptation of the learning model to the demands of the 21st century, particularly in technology and information fields, is crucial for acquiring relevant knowledge [29]. The cryptography course is one of the courses that has made a major contribution to the development of information technology. Cryptography courses are related to many other courses. It has a mathematical basis and programming algorithms in the manufacturing process, while in implementation, it utilizes a programming language [6]. The cryptography course is less popular among students because it is considered difficult. This is because the learning model implemented is not appropriate. To achieve better results in teaching cryptography, new approaches are required, as traditional methods are ineffective. Products derived from the POGIL learning model-metaphorming meet the valid criteria with an average model validity of 0.83. Thus, this model can be recommended for the intended learning and meets the needs of 21st-century learning.

6 CONCLUSION

In conclusion, this study has succeeded in developing POGIL metaphorming, which is designed to enhance student learning processes and outcomes in cryptography courses. The product developed is a model with a six-phase syntax that serves as a guide for implementing the model. Several supporting products that serve as support systems for model implementation include the POGIL model book "Metaphorming," which provides background information on the model's development and learning syntax; the lecturer's guidebook containing the syntax and activities for the lecturer to implement learning; creation RPS and evaluations; a student guide with syntax and activities for students to apply model learning; and student activity sheets to enhance learning and innovation skills. All products are deemed highly valid based on expert opinion, indicating that the product is suitable for use according to its intended function.

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