Developing Mathematics Assessment and Learning Packages in Basic Education Integrated with Web-Based Computational Thinking Skills

Hisyam Ihsan, Fajar Arwadi(✉), and Sutamrin

Mathematics Department, Universitas Negeri Makassar, Makassar 90222, Indonesia
fajar.arwadi53@unm.ac.id

Abstract. Computational thinking is a fundamental skill for everyone, not just computer scientists. It has been promoted as a skill as fundamental for everyone as numeracy and literacy. The idea of integrating computational thinking into mathematics education has been issued for a long time. However, there is no research about developing packages for assessing and learning mathematics in primary education integrated with web-based computational thinking skills. Therefore, this study aims at conducting that development. This research is a type of research that adopts the principles of Design-based Research. The findings suggest that the conceptual framework for assessment and learning in primary education is integrated with computational thinking skills in mathematics, following the latest developments in science and technology. Moreover, the resulting design principles are assessment and learning design models at the basic education level integrated with 21st-century competencies-computational thinking skills in web-based mathematics (AP-KBKM Model). Furthermore, the EB-based tools for assessing and learning mathematics for grades 1–9 integrated with computational thinking skills (supporting tools for the AP-KBKM model) have been developed as valid, reliable, practical prototypes, and effective.

Keywords: Stochastic Model Checking · Assume-Guarantee Reasoning · Symmetric Assume-Guarantee Rule · Learning Algorithm · Probabilistic Automata

1 Introduction

It has long been proposed to incorporate computational thinking into mathematics teaching. In 1980, Papert coined the phrase to describe the Logo programming language, which he thought could improve children's thinking and problem-solving. The learning environment called Logo suggests that learning math in Logo is similar to learning French by living in France. It also confirms the idea that math is a language for computer communication. Computer-mediated communication training can impact how students learn in general. The computer interface can be intuitive enough that learning to communicate with it is a natural progression [1].

A. A. Patak and A. H. Hasim (Eds.): W-SHARE 2022, ASSEHR 762, pp. 150–157, 2023.
https://doi.org/10.2991/978-2-38476-084-8_21

In recent times, computational thinking has come to be regarded as a collection of cognitive abilities and problem-solving processes that should be incorporated into every child's education [2]. The trend of adding some forms of computer coding to the curriculum is an international phenomenon [3]. Emphasize that the United Kingdom, Finland, Estonia, and the United States all have computational thinking curriculum mandates [4].

Highly developed computational thinking, in contrast to how Logos and mathematics were integrated to support and improve the learning of other subject areas, computational thinking appears to have been viewed as a curriculum goal in curricula around the world.

However, Gadanidis and his colleagues found a natural link between computational and mathematical thinking. This link exists not only in the logical structure or the capability of computational thinking to mathematical model relationships but also in integrating computational thinking into mathematical thinking [3]. It offers a fresh, imaginative method for resolving mathematical issues and broadens the pool of mathematics that students at all levels can use. This skill, closely related to critical thinking, is necessary for the 21st century.

In mathematics, one form of critical thinking is identifying patterns between cases, generalizing these patterns, formulating solutions that are generally accepted as applicable to all cases, and identifying excluded cases. The advancement of computer science necessitates these skills. Computational algorithms on computers necessitate the capacity to recognize general patterns and outliers. This competency is also known as computational thinking skills.

Anyone, not just computer scientists, should be able to think computationally. It has been marketed as a competency essential for everyone, such as literacy and math. Cognitive abilities involve the processes used to reason and solve problems. When it comes to reading, writing, and arithmetic, we must add computational thinking to the analytical abilities of every child. Because it focuses on procedures and techniques for resolving issues and producing quantifiable solutions, computational thinking differs significantly from digital literacy and competence. It has been marketed as a competency essential to everyone, such as literacy and math [5, 6].

However, no research studies have developed tools for assessing and learning mathematics in primary education integrated with web-based computational thinking skills. So, in this study, the authors are interested in researching this issue. So, the research problem of this study is how to develop tools for assessment and learning mathematics in primary education integrated with web-based computational thinking skills.

2 Methods

2.1 Research and Type Design

This research is a type of research that adopts the principles of Design-based Research. As it is known, instructional design is how educational tools and resources are designed, developed, and implemented to help students achieve their learning outcomes. The basic design-based research process involves developing solutions (called interventions) to problems [7]. The effectiveness of the intervention is then evaluated by putting it into practice. Once more data is collected, iterations can be modified and retested.

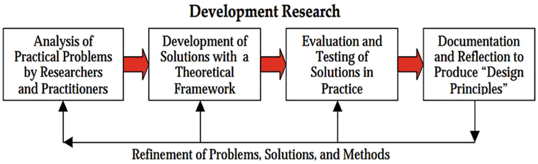

Fig. 1. Design-Based Research Framework [12].

This Design-Based Research strategy aims to produce novel learning, teaching, process design, and educational reform conceptualizations.

As in Fig. 1, Iterative analysis (cycles), design, development, and implementation based on collaboration between researchers and practitioners in real-world settings are all part of the systematic and adaptable research methodology known as "design-based research," which aims to improve educational practice while sensitively contextualizing design principles and theory [8–10]. Educational design research is an activity that is carried out systematically (including research design, data collection, data analysis, and reporting), which aims to improve the quality of prototypical interventions and the accompanying design principles (intervention theory) [11].

Based on this type of research, the research objectives, as stated in the roadmap, are to develop interventions, namely the Assessment Design Model and integrated mathematics learning skills of computational thinking in primary education (AP-KBKM), which have a twofold yield in the form of (1) development production research-based interventions as solutions to complex problems, namely instructional packages or courseware, and (2) production of design principle constructions, namely the AP-KBKM model framework. The design model overviews system implementation (AP-KBKM Model) and its resources (AP-KBKM supporting tools).

2.2 The Development Procedure

To achieve the research objectives in this study, two development cycles were used following the framework in Fig. 1 with prototypical intervention criteria (design & develop prototypes and design principles) through three stages of design and four qualities, relevance, consistency, practicality, and effectiveness. The prototype development mechanism is presented in Fig. 2.

The three design stages are the global design stage of the intervention, partly complex intervention, and complete intervention, with four quality criteria: relevance, consistency, practicality, and effectiveness.

Proposes four general criteria for high-quality interventions; namely, the intervention components must be based on up-to-date knowledge (content validity), and all components must be related to one another (constructive validity) [13]. The intervention is deemed valid if it complies with these requirements. Another sign of a high-quality intervention is that it is accessible and usable by the target audience, which includes educators and students, so they can use the resources in a way that essentially advances the development objectives. The intervention can be regarded as practical if these requirements are satisfied. Having the desired effect, or being effective, is the third characteristic of high-quality interventions.

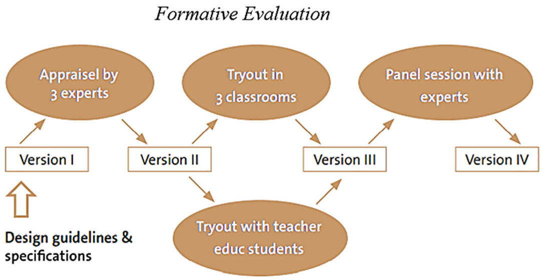

Fig. 2. Prototype Development Flow and Evaluation.

2.3 Population and Sample

The population is the universe of discourse, the boundaries we discuss and apply conclusions, and the set of actual or hypothetical items defined by a common characteristic to which questions and answers (discussion) is applied. This study's target population of concern is all educators and students in education units for the primary education level in the formal education pathway in Makassar City. The basic education units (grades 1–9) in the formal education pathway are primary schools/Islamic madrasas and junior high schools. For development research, the target population was selected based on the criteria for the ability of educators to participate in research. Therefore, the target population is Elementary School Multilevel Makassar, Junior High School 8 Makassar, and Telkom Makassar. Educators and students participating in this study are assumed to be a random sample. The sample is a small sample of the population, which is never the same size as the population. A sample is an unbiased set of observations (individuals, animals, items, data) drawn from a population. Sampling is the selection of several population units to represent the whole aggregate. Therefore, we must ensure that members of the sample are as similar as possible to the population regarding the research objectives.

3 Results and Discussion

The development activities in this cycle are to complete the prototype that was produced in the first cycle as follows:

(1) Preparation of KBKM class 1–6 learning tools.

Preparation of KBKM class 1–6 learning tools based on blueprints that have been produced previously. These tools are (i) Class 1–6 KBKM integrated Learning Plan and (ii) KBKM integrated lesson plan attachments in the form of Material References, student worksheets, Assessments, and Assignments.

(2) Development of a problem set for the KBKM 1–6 performance assessment.

As was done in the first year, the KBKM 1–6 performance assessment question package also follows the concept of developing the KBKM assessment question package for grades 7–9. The KBKM 1–6 performance assessment question package is divided into two packages: the KBKM 1–3 and 4–6 performance assessment question packages.

(3) Completing the web design (e-learning) and the Guide.

Materials and learning tools for classes 1–6 KBKM produced and evaluated by experts and practitioners are included in the e-learning at Learning Management System. Then a web-based learning guide (e-learning) is created. The prototype development results were evaluated using the formative evaluation method. The prototype is Prototype II. This evaluation is a partly detailed and complete intervention with the criteria of practicality and effectiveness so that the resulting product evaluation results based on Fig. 2 are called prototype III.

Before compiling the instruments for evaluation purposes in the implementation of the pilot study, an evaluation of the newly developed prototype was first carried out to obtain prototype II and then the packaging of the entire product.

As in the first cycle, in this second cycle, an evaluation was also carried out on the newly developed prototype (prototype I) to see the achievement of the relevance and consistency criteria, namely (a) Class 1–6 KBKM Learning Sets, consisting of lesson plans and attachments, and (2) Question Package (Problem Set) KBKM Performance Assessment 1–6. Furthermore, tests were carried out based on the data, revisions, and improvements and then determined prototype II.

Before compiling instruments for evaluation purposes in implementing a pilot study, an evaluation of the prototype that has just been developed is first carried out to obtain prototype II and then the packaging of the entire product.

(4) Prototype of Learning Plan and Attachment to Learning Plan KBKM Classes 1–6

The results of the data analysis show that by using criterion 3 (following the theoretical concept), the average score of the expert's assessment of the instrument items means no correction is required for the prototype. Furthermore, the results of the validity and reliability tests based on the formulas show that the content validity coefficient KVI = 94.60% and the reliability coefficient KR = 85.30%, each of which exceeds the criteria (>75%), which means intervention through the prototype is valid and reliable. This also means that the prototype is logically designed according to the latest knowledge and can perform its function adequately.

Inferential analysis results. Analysis requirements through normality and homogeneity tests have been fulfilled ($p > 0.05$). The results of the ANOVA test for classes 2, 4, and 6 lesson plans for lesson plans (as samples) with the dimensions of IR, MS, TP, KP, and AS, show that at a significance level of $\alpha = 0.05$, p-value $= 0.326 > 0.05$ which means Ho is accepted or there is no effect of the prototype intervention dimension in the population. This shows that all the concept dimensions in the prototype intervention are declared fit.

(5) Prototype Problem Set Performance Assessment KBKM 1–6

The results of the data analysis show that by using criterion 3 (following the theoretical concept), the average score of the expert's assessment of the instrument items means no correction is required for the prototype. Furthermore, the results of the validity and reliability tests based on formulas show that the content validity coefficient KVI = 92.80% and the reliability coefficient KR = 84.40%, each exceeding the criteria (>75%) means intervention through the prototype is valid and reliable. This also means that the prototype is logically designed according to the latest knowledge and can perform its function adequately in inferential analysis results. Analysis requirements through normality and homogeneity tests have been fulfilled (each with $p > 0.05$). The results of the F-ANAVA test based on the model for the KBKM 1–3 Problem Set with the IS, BH, PS, and TS dimensions, show that at a significance level of $\alpha = 0.05$, a p-value = 0.976 > 0.05 is obtained, which means Ho accepted or no dimensional effect of the prototype intervention in the population. This shows that all dimensions in the prototype intervention are declared fit (according) to the data conditions as a model. Thus, the intervention on the prototype I Problem Set KBKM 1–3 is declared relevant and consistent.

(6) KBKM 1–9 e-Learning Web Prototype (Complete)

The results of the data analysis show that by using criterion 3 (quite according to the theoretical concept), the average score of the expert's assessment of the instrument items means that no correction is required for the prototype. Furthermore, the results of the validity and reliability tests are based on formulas that the content validity coefficient KVI = 95.50% and the reliability coefficient KR = 89.20%, each of which exceeds the criteria (> 75%), which means intervention through the prototype is valid and reliable. This also means that the prototype is logically designed according to the latest knowledge and can perform its function adequately—inferential analysis results. Analysis requirements through normality and homogeneity tests have been fulfilled. The results of the ANOVA (F-test) based on the model for KBKM Web Design with DA, DB, and DC dimensions show that at a significance level of $\alpha = 0.05$, p-value = 0.940 > 0.05 is obtained, which means that all conceptual dimensions in intervening prototypes declared fit (appropriate). Thus, the intervention on the LMS e-Learning KBKM Web Design prototype is declared relevant and consistent.

4 Conclusion

Based on the general and specific research objectives that refer to the roadmap and double yield of the research design based on the roadmap, the conclusions that can be drawn through the stages of R & D research as basic research are: (1) The conceptual framework for assessment and learning in primary education is integrated with computational thinking skills in mathematics, following the latest developments in science and technology; (2) The resulting design principles are assessment and learning design models at the basic education level integrated with 21st-century competencies-computational thinking skills in web-based mathematics (abbreviated as the AP-KBKM Model); (3) Web-based tools for assessing and learning mathematics for grades 1–9 integrated with computational thinking skills (supporting tools for the AP-KBKM model) have been developed as valid, reliable, practical, and effective prototypes.

The prototype set consists of (a) a blueprint as a guideline for implementing learning and measuring computational thinking skills in grades 1–9 mathematics which has been compiled through competency analysis based on the 2013 mathematics curriculum and refers to the framework that has been developed, (b) Class 1–9 KBKM learning materials as a reference in developing learning in class, (c) learning implementation plans (RPP) and attachments (reference materials, student worksheets (LKP), project assignments, and homework) are integrated KBKM as a guideline for learning stages and activities in class, (d) LMS web E-learning KBKM Classes 1–9, and (e) question packages (problem sets) for KBKM performance assessment 1–3, 4–6, and 7–9.

Acknowledgements. The National Natural Science Foundation of China supported this work (61303022), the Natural Science Major Project of Jiangsu Higher Education Institutions (17KJA520002), and the Nanjing Scientific & Technological Innovation Project for Outstanding Overseas Returnees.

References

1. S. Papert, "Children, computers and powerful ideas," *New York Basic Books*, vol. 10, p. 1095592, 1990.
2. J. M. Wing, "Computational thinking and thinking about computing," *Philos. Trans. R. Soc. A Math. Phys. Eng. Sci.*, vol. 366, no. 1881, pp. 3717–3725, 2008.
3. G. Gadanidis, R. Cendros, L. Floyd, and I. Namukasa, "Computational thinking in mathematics teacher education," *Contemp. Issues Technol. Teach. Educ.*, vol. 17, no. 4, pp. 458–477, 2017.
4. D. Kotsopoulos *et al.*, "A pedagogical framework for computational thinking," *Digit. Exp. Math. Educ.*, vol. 3, no. 2, pp. 154–171, 2017.
5. S. Bocconi, A. Chioccariello, G. Dettori, A. Ferrari, and K. Engelhardt, "Developing computational thinking in compulsory education-Implications for policy and practice," Joint Research Centre (Seville site), 2016.
6. S. Al-Fedaghi and A. A. Alkhaldi, "Thinging for computational thinking," *arXiv Prepr. arXiv1903.01900*, 2019.
7. C. Johnson *et al.*, "Using design-based research to develop meaningful online discussions in undergraduate field experience courses," *Int. Rev. Res. Open Distrib. Learn. IRRODL*, vol. 18, no. 6, pp. 36–53, 2017.
8. W. A. Sandoval, "Developing learning theory by refining conjectures embodied in educational designs," *Educ. Psychol.*, vol. 39, no. 4, pp. 213–223, 2004.
9. Q. Wang, W. Q. Den Haag, L. S. Schele, P. Printpartners, and I. Enschede, "Computer support for multimedia curriculum design, Doctoral dissertation," 2001.
10. T. Amiel and T. C. Reeves, "Design-based research and educational technology: Rethinking technology and the research agenda," *J. Educ. Technol. Soc.*, vol. 11, no. 4, pp. 29–40, 2008.
11. T. Plomp and N. Nieven, "Educational Design Research-Part A: An Introduction Enschede: Netherland Institute for Curriculum Development (SLO) PQ4R Strategy Accompanied by Refutation Text reading," 2013.
12. T. C. Reeves, "Enhancing the worth of instructional technology research through 'design experiments' and other development research strategies," *Int. Perspect. Instr. Technol. Res. 21st century*, vol. 27, pp. 1–15, 2000.
13. T. Plomp and N. M. Nieveen, *An introduction to educational design research: Proceedings of the seminar conducted at the East China Normal University, Shanghai (PR China), November 23–26, 2007*. Stichting Leerplan Ontwikkeling (SLO), 2010.