The Elementary Education Assessment and Learning Integrated 21st Century-Computational Thinking Skills in Mathematics: Global Design Stage

Hisyam Ihsan*, Fajar Arwadi, Sutamrin Sutamrin

Mathematics Education Program, Universitas Negeri Makassar, Makassar, South Sulawesi, Indonesia
Corresponding author. Email: hisyamihsan@unm.ac.id

ABSTRACT

This research aims to obtain the assessment models/designs and learning at the basic level of education integrated with computational thinking in web-based mathematics lessons/computers. The method used is design-based research to gain insight into computational thinking and encourage computational thinking skills among learners in math lessons. In the first year, it has developed a conceptual framework, blueprint, and supporting tools for assessment and mathematics learning (Grade 7-9) integrated with computational thinking, including its web design. The research findings are design principles in the form of models/learning designs and assessments integrated with computational thinking that will be detailed in the following year stages: Partly Detailed and Complete Intervention Stage.

Keywords: *Computational Thinking; Assessment, Teaching and Learning, School Mathematics, Instructional Model*

1. INTRODUCTION

In recent years, computational thinking has become a highly desirable topic in mathematics education [1] due to some issues. [2] have considered computational thinking and mathematics as “natural companions.” In addition, [3] argues that there is a natural relationship between computational thinking and mathematics in terms of logical structure and the ability to explore and model mathematical relationships. [4] claim that both computational and mathematical thinking are the approaches of thinking by adopting the concepts of cognition, metacognition, and disposition centers on problem-solving. In addition, they also recognize and cultivate social-cultural learning opportunities that shape ways of thinking and practice that reflect the real world.

In mathematical studies, critical thinking is the ability to find patterns among cases, generalize the pattern and then formulate to get a generally accepted solution to be applied in all cases and identify excluded cases. Advances in computer science require these skills; computational algorithms on computers require identifying common patterns and exceptional cases. This ability is commonly referred to as computational thinking.

Computational thinking is one of the biggest buzzwords in education—even referred to as the '5th C' of 21st-century skills, which lately has caught the attention of educators in a variety of subjects—from science to mathematics steadily to social studies. "4C (critical thinking, creativity, collaboration, and communication) has gained growing recognition as an important element of the school curriculum. This shift has encouraged the use of pedagogy and frameworks such as project-based learning, inquiry learning, and deeper learning at all levels of kindergarten-12 schools that emphasize high-level thinking (HOTS) throughout the learning process. With the advancement of technology and information in Industry 4.0, experts' consensus is that computational thinking is another core skill or "5 C" as a 21st-century skill, which becomes an essential competency for learners. This does not mean that every child is expected to be a computer scientist, nor is basic literacy in mathematics and science considered essential for all children to understand how the world works. Thus, education should address the development of knowledge and skills related to computation, which is now integrated with each profession.

Each country has a vision of mathematical competence and organizes its schools to achieve them as expected results. Historically, mathematical competence has included basic arithmetic skills or operations, including addition, subtraction, multiplication, and division of numbers, decimals, and fractions; percentage calculation; and calculating the area and volume of simple geometric shapes. In recent times, digitalization in many aspects of life has occurred. The data are used to make personal decisions that initially involve education and career planning, and, later in life, health, and investment, as well as major social challenges to deal with areas such as climate change, government debt, population growth, the spread of pandemic diseases and the global economy. It has reshaped what it means to be mathematically competent and well-equipped to participate as a wise, engaged, and reflective citizen in the 21st century.

2. METHOD

This research method adopts the principles of Design-based Research [5] proposed that design-based research "has a solid foundation on previous research and theories and is conducted in an educational environment. It is undertaken to track the evolution of learning in complex classrooms and schools, tests and builds learning theories, and produces instructional tools that withstand the challenges of everyday practice". In addition, [6] stated that design-based research is "a series of approaches, with the intent of producing new theories, artifacts, and practices that explain and potentially impact learning and teaching in naturalistic settings."

As in Figure 1, [8], [9], and [10] also explained that Design-Based Research is a systematic and flexible research methodology, which aims to improve educational practice using repetitive analysis (cycle), design, development, and implementation, based on collaboration between researchers and practitioners in real-world settings, and leads to the contextualization of design principles and sensitive theories.

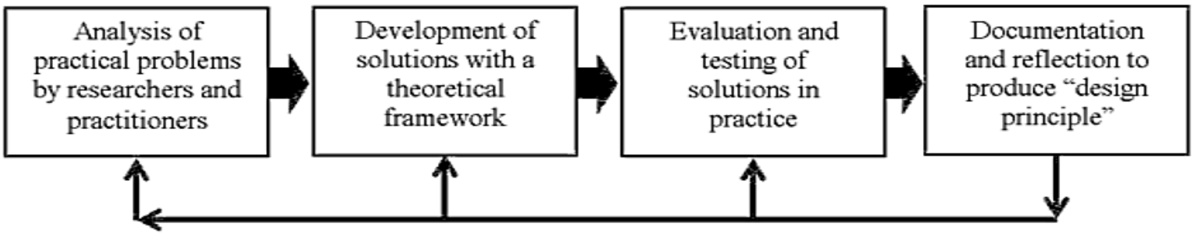

Figure 1. Phases in Design-Based Research [7].

3. RESULT AND DISCUSSION

Based on the research as mentioned above design, the stages, and the results of the implementation of research for the first cycle as a global design are as follows.

3.1. Practical Problem Analysis

The first activity of design-based research, as in [7] and [11] is the analysis of practical problems by a team of researchers and practitioners. Practical problem analysis is a pre-intervention based on the formulation of the problem in the proposal. The activity results consist of literature review, reference selection, collection and analysis of preliminary data, and identification and analysis of the need to see alternative solutions/ interventions. Initial data collection through observation, interviewing with practitioners (teachers and school leaders), and document studied. Identification and analysis of needs adapt [12] and [13] By looking at performance gaps, finding the cause of the problem, and choosing the best intervention alternative

3.2. Solution Development (Theoretical Framework)

Solution Development (or Intervention) begins with preparing a conceptual framework of assessment and learning on the integrated Primary Education of 21st-century competence-computational thinking skills in mathematics (KBKM). It refers to the results of the work [14] and the PISA Mathematical Framework 2021 [15], hence the development activities begin by examining the definition, scope, and theoretical basis of the existing literature, including conference results in selected databases, and focusing on Computational Thinking. To do so, systematic text analysis procedures are used as qualitative content analysis. The study of the components of computational thinking as an indicator of skills in computational thinking, [16], [17], and [18] as the primary reference in its formulation as in the following Table 1.

Table 1. Components of Computational Thinking

Component	Description
Decomposition	Breaking problems into parts
Pattern recognition	Analyzing the data, look for patterns to make sense of the data
Abstraction	Removing unnecessary details and focusing on the critical data

Component	Description
Modelling-simulation	Creating models or simulations to represent processes
Algorithms	Creating a series of ordered steps taken to solve a problem
Evaluation	Determining the effectiveness of a solution, generalizing, and applying it to new problems

Based on the definition of mathematics, the school's mathematical content is built on a combination of the categories of mathematical content in the PISA 2021 framework. Computational thinking skills (KBK) are characterized by using one or more of the six components of computational thinking (in Table 1) or using a combination of decomposition, recognizing patterns, abstraction, modeling/simulation algorithms, and evaluation in solving problems.

3.3. Practical Problem Analysis

The results obtained in the form of prototypes are evaluated using the formative evaluation method of the prototype as in [19]. This evaluation uses the criteria of quality relevance and consistency in the global design stage so that the results of product evaluation are obtained as in [20] called prototype version II.

The stages of evaluation consist of Development of Data Collection Instruments, Data Collection, Data Processing and Analysis, and Documentation and Reflection (Produce Design Principles)

4. CONCLUSION

The results of the intervention are that conceptual frameworks and instructional packages (prototype II) in the form of blueprints, materials, devices, problem packages, and web design assessments and integrated learning of 21st-century computational thinking skills in Mathematics satisfy the evaluation criteria at the stage of global design development, i.e., relevance and consistency. At this stage of intervention, the Design Principles design Assessment Model and Integrated Mathematical Learning web/computer-based computing thinking skills are formulated that will be detailed in the next development cycle through pilot study in the development stage of partly detailed and complete intervention.

ACKNOWLEDGMENT

On this occasion, I would like to express my greetings and gratitude to all those who have helped in conducting this research, especially the team members, lecturers and teachers who participated, mainly thanks to the Rector and his staff at the UNM Research Institute. Thank you also to the Ministry of Education and Technology who has funded the research through contract No. 127/E4.1/AK.04.PT/2021 and 114/UN36.9/LP2M/2021.

REFERENCES

[1] L. Broley, C. Buteau and E. Muller, "(Legitimate peripheral) computational thinking in mathematics," in CERME, Dublin, Ireland, 10, Feb 2017.

[2] L. English, "On MTL’s Second Milestone: Exploring Computational Thinking and Mathematics Learning," Mathematical Thinking and Learnin, vol. 20, no. 1, pp. 1-2, 2018. DOI: https://doi.org/10.1080/10986065.2018.1405615.

[3] G. Gadanidis, J. M. Hughes, L. Minniti and B. J. G. White, "Computational Thinking, Grade 1 Students and the Binomial Theorem," Digital Experiences in Mathematics Education, vol. 3, no. 2, pp. 77-96, 2016. DOI: https://doi.org/10.1007/s40751-016-0019-3.

[4] M. Kallia, S. P. v. Borkulo, P. Drijvers, E. Barendsen and J. Tolboom, "Characterising computational thinking in mathematics education: a literature-informed Delphi study," Research in Mathematics Education, vol. 23, no. 2, pp. 159-187, 2021. https://doi.org/10.1080/14794802.2020.1852104.

[5] R. Shavelson, D. Phillips, L. Towne and M. Feuer, "On the Science of Education Design Studies," Educational Researcher, vol. 32, no. 1, pp. 25-28, 2003. Doi:10.3102/0013189X032001025.

[6] S. Barab and K. Squire, "Design-Based Research: Putting a Stake in the Ground," Journal of the Learning Sciences, vol. 13, no. 1, pp. 1-14, 2004. DOI: 10.1207/s15327809jls1301_1.

[7] T. C. Reeves, "Enhancing the Worth of Instructional Technology Research through “Design Experiments” and Other Development Research Strategies," in International Perspectives on Instructional Technology Research for the 21st Centur, New Orleans, LA, USA., Paper presented on April 27, 2000.

[8] W. A. Sandoval and P. Bell, "Design-Based Research Methods for Studying Learning in

Context: Introduction," Educational Psychologist, vol. 39, no. 4, pp. 199-201, 2004. DOI: 10.1207/s15326985ep3904_1.

[9] F. Wang and M. J. Hannafin, "Design-based research and technology-enhanced learning environments," Educational Technology Research and Development, vol. 54, no. 4, pp. 5-23, 2005. DOI: https://doi.org/10.1007/BF02504682.

[10] T. Amiel and T. C. Reeves, "Design-Based Research and Educational Technology: Rethinking Technology and the Research Agenda.," Journal of Educational Technology & Society, vol. 11, no. 4. International Forum of Educational Technology & Society, p. 29–40, 2008. http://www.jstor.org/stable/jeductechsoci.11.4.29..

[11] W. Cotton, L. Lockyer and G. Brickell, "A Journey Through a Design-Based Research Project. In G. Siemens & C. Fulford (Eds.)," in Proceedings of ED-MEDIA 2009--World Conference on Educational Multimedia, Hypermedia & Telecommunications, Honolulu, HI, USA: Association for the Advancement of Computing in Education (AACE), 2009. https://www.learntechlib.org/primary/p/31662.

[12] P. Rodberg, "Analyzing Performance Problems, or You Really Oughta Wanna. By Robert F. Mager and Peter Pipe. Belmont, Calif.: Pitman Learning, Inc., 1984.," NASSP Bulletin, vol. 69, no. 483, p. 132–133, 1985. https://doi.org/10.1177/019263658506948326.

[13] A. Rossett, Training needs assessment, Englewood Cliffs, N.J.: Educational Technology Publications, 1987.

[14] i. Kalelioglu, Y. Gulbahar and V. Kukul, "A Framework for Computational Thinking Based on a Systematic Research Revie," Baltic Journal of Modern Computing, vol. 4, no. 3, pp. 583-596, 2016.

[15] OECD, PISA 2021 Mathematics Framework (second draft), Paris: OECD Publishing, 2018.

[16] A. Green, "Put your (computational) thinking cap on!," in CSIROscope, 2019. https://blog.csiro.au/put-your-computational-thinking-cap-on/.

[17] A. Storey, Bebras Australia Computational Thinking Challenge: Solution Guide., Australia: Digitalcareers, (adt.) 2018.

[18] F. Bavera, T. Quintero, M. Daniele, F. Buffarini, P. Pesado and M. Arroyo, "Computational Thinking Skills in Primary Teachers: Evaluation Using Bebras," in Computer Science – CACIC 2019, Cham, Springer International Publishing, 2020. DOI: https://doi.org/10.1007/978-3-030-48325-8_26, pp. 405-415.

[19] N. Nieveen, "Formative Evaluation in Educational Design Research," in Plomp, T., & Nieveen, N. M. (Eds.) (2010). An introduction to educational design research: Proceedings of the seminar conducted at the East China Normal University, Shanghai, 2007.

[20] J. v. d. Akker, B. Bannan, A. Kelly, N. Nieveen and T. Plomp, Educational Design Research: Part A: An introduction., Netherland: Enschede: SLO., 2013. International - SLO p.29.