

DESIGN OF TEACHING MATERIALS WITH PYTHON-ASSISTED NUMERICAL METHODS TO DEVELOP STUDENTS' MATHEMATICAL CREATIVE THINKING ABILITY

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Abstract

This study aims to design and examine the feasibility of Python-assisted numerical methods teaching materials in the form of a problem-based learning module intended to support the development of students' mathematical creative thinking abilities. The research adopts a research and development (R&D) approach using the ADDIE model and is limited to the Analysis, Design, and Development phases. In the analysis phase, curriculum documents and numerical methods course syllabi were reviewed and interviews were conducted with lecturers to identify course learning outcomes, key indicators, and students' difficulties related to numerical methods and mathematical creative thinking. In the design phase, the structure and components of the module were specified, including orientation sections, explanations of concepts and procedures, worked examples, practice exercises, problem-based tasks integrating Python programming, evaluations, and answer keys, all aligned with indicators of mathematical creative thinking. In the development phase, a draft of the module was produced and subjected to expert validation by media, content, and education experts using a Likert-scale instrument, followed by a small-group trial with students. The expert validation results showed an average score of 75.26% in the "Strong" category, while student responses reached an average of 92.3% in the "Very Strong" category, indicating that the module is valid and highly practical for numerical methods learning. These findings suggest that the Python-assisted, problem-based numerical methods module is feasible for use in lectures and has promising potential to support the development of students' mathematical creative thinking abilities, which should be further investigated through subsequent experimental or quasi-experimental studies that directly measure learning outcomes and creative thinking.

Keywords: teaching materials; numerical methods; Python; problem-based learning; mathematical creative thinking.

Abstrak

Penelitian ini bertujuan untuk merancang dan menguji kelayakan bahan ajar metode numerik berbantuan Python dalam bentuk modul pembelajaran berbasis masalah yang ditujukan untuk mendukung pengembangan kemampuan berpikir kreatif matematis mahasiswa. Penelitian menggunakan desain research and development (R&D) dengan model ADDIE dan dibatasi pada tiga tahap, yaitu Analisis, Desain, dan Pengembangan. Pada tahap analisis dilakukan telaah dokumen kurikulum dan silabus mata kuliah metode numerik serta wawancara dengan dosen untuk mengidentifikasi capaian pembelajaran, indikator kunci, dan kesulitan mahasiswa terkait metode numerik dan kemampuan berpikir kreatif matematis. Pada tahap desain ditetapkan struktur dan komponen modul, yang meliputi bagian orientasi, penjelasan konsep dan prosedur, contoh soal dan penyelesaian, latihan, tugas berbasis masalah yang mengintegrasikan pemrograman Python, evaluasi, dan kunci jawaban, yang seluruhnya diselaraskan dengan indikator kemampuan berpikir kreatif matematis. Pada tahap pengembangan dihasilkan draf modul yang kemudian divalidasi oleh ahli media, ahli materi, dan ahli pendidikan menggunakan instrumen skala Likert, serta diujicobakan secara terbatas kepada mahasiswa. Hasil validasi ahli menunjukkan skor rata-rata sebesar 75,26% dengan kategori "Kuat", sedangkan respons mahasiswa mencapai rata-rata 92,3% dengan kategori "Sangat Kuat", sehingga modul dinyatakan valid dan sangat praktis untuk pembelajaran metode numerik. Temuan ini menunjukkan bahwa modul metode numerik berbasis masalah berbantuan Python layak digunakan dalam perkuliahan dan memiliki potensi yang menjanjikan untuk mendukung pengembangan kemampuan berpikir kreatif matematis mahasiswa, yang perlu dikaji lebih lanjut melalui penelitian efektivitas pada studi eksperimental atau kuasi-eksperimental berikutnya.

Kata kunci: bahan ajar; metode numerik; Python; pembelajaran berbasis masalah; berpikir kreatif matematis

INTRODUCTION

Numerical methods are techniques for solving problems formulated in the form of mathematical models using simple arithmetic operations (Wulan et al., 2017). Problems that are difficult or impossible to solve analytically can often be approximated using numerical methods, so this course plays a strategic role in equipping students with applied mathematical problem-solving skills (Doli Nasution et al., 2017). However, despite relying on simple arithmetic operations, numerical methods are often perceived as difficult and abstract by students, which leads to low interest and difficulty in understanding the material (Doli Nasution et al., 2017). At the institution where the author teaches, there is also a lack of engaging numerical methods teaching materials that can support students' independent learning.

In the context of 21st-century education, mathematical creative thinking ability is considered an essential competence that students must possess to face increasingly complex technological and global challenges (Khoerunisa & Habibah, 2020). Mathematical creative thinking generally includes indicators such as fluency in generating ideas, flexibility in using various strategies, originality in proposing solutions, and elaboration in developing and refining ideas when solving mathematical problems (Akhsani et al., 2025; Indrapangastuti et al., 2025). Various studies in mathematics education show that learning designs that emphasize non-routine problem solving, exploration of multiple strategies, and reflection can support the development of creative and higher-order thinking skills (Hafiza et al., 2023; Rahmawati & Sari, 2025; Riani & Pratama, 2025; Siregar & Lubis, 2023). Learning activities in numerical methods have the potential to develop these indicators, for example through exploration of several numerical techniques, comparison of approximation results, and interpretation of errors in different solution strategies, especially when students are encouraged to seek alternative approaches and justify their choices (Akhsani et al., 2025; Wulan et al., 2017).

One important component in learning is the availability of teaching materials that are systematically arranged based on competencies, objectives, and learning activities (Pannen & Purwanto, 2001; Prastowo, 2011). Well-designed teaching materials can guide students to learn independently, provide meaningful practice, and support the achievement of higher-order thinking skills (Nurhayati, 2017; Febrianti et al., 2021). However, the availability of

numerical methods teaching materials that are easy to understand and at the same time oriented towards developing students' mathematical creative thinking abilities is still limited (Doli Nasution et al., 2017). Several development studies show that modules or other teaching materials designed using systematic development models such as ADDIE can produce valid and practical products that are positively perceived by students and lecturers (Muruganantham, 2015; Nurhayati, 2017; Putra F. H. K. et al., 2024). Nevertheless, many of these products are still oriented toward conceptual understanding and procedural skills, and only a few explicitly integrate problem-based learning and programming activities to foster creativity in numerical methods or computational mathematics contexts (Putra A. R. & Susanti, 2022; Febrianti et al., 2021).

The use of computer programming applications can facilitate numerical computation processes and open opportunities for students to explore various solution strategies more flexibly (Doli Nasution et al., 2017). In this research, Python is used as the main programming language because it has several advantages compared to other applications, including simple syntax, efficiency, speed, versatility, popularity, and strong community support (Alfarizi et al., 2023; Harismawan et al., 2018). Previous studies and implementations also indicate that the integration of programming tools and interactive learning media can increase student engagement and provide richer learning experiences in computational mathematics and numerical methods courses (Doli Nasution et al., 2017; Putra F. H. K. et al., 2024). By integrating Python into numerical methods learning, students are expected not only to perform calculations more efficiently, but also to experiment with different methods, modify parameters, and observe the effects of these changes on approximation results, which can support the development of mathematical creative thinking (Akhsani et al., 2025; Alfarizi et al., 2023).

Problem-based learning (PBL) is one of the learning models that has been widely reported to be effective in improving students' mathematical creative thinking abilities (Hafiza et al., 2023; Rahmawati & Sari, 2025; Siregar & Lubis, 2023). Empirical studies show that students who learn with PBL tend to achieve higher gains in indicators of fluency, flexibility, and originality compared with students who experience conventional learning (Hafiza et al., 2023; Riani & Pratama, 2025). Meta-analysis research also confirms that PBL and open-ended approaches generally have a strong effect size on mathematical creative

thinking abilities across different educational levels and mathematical topics (Riani & Pratama, 2025; Febrianti et al., 2021). In addition, several studies on the development of PBL-based modules indicate that such teaching materials can effectively support students' independent learning and problem-solving skills (Putra A. R. & Susanti, 2022; Nurhayati, 2017). These findings support the assumption that the design of numerical methods teaching materials that combine PBL and programming activities has the potential to encourage the emergence of mathematical creative thinking.

Based on the description above, the research problem can be formulated as follows: "How to design Python-assisted numerical methods teaching materials in the form of a problem-based learning module that is feasible and practical and has the potential to develop students' mathematical creative thinking abilities?" Therefore, the purpose of this study is to design and test the feasibility of Python-assisted numerical methods teaching materials in the form of a problem-based module that supports the development of students' mathematical creative thinking abilities.

METHODS

This study employs a research and development (R&D) design because it aims to produce feasible and practical teaching materials that support numerical methods learning in higher education (Ruseffendi, 2005). In accordance with the characteristics of instructional product development, the ADDIE model was used as the development framework. The ADDIE model consists of five phases, namely Analysis, Design, Development, Implementation, and Evaluation, but this research was limited to the first three phases (Analysis, Design, and Development) because the focus was on product feasibility rather than effectiveness testing (Muruganatham, 2015; Nurhayati, 2017).

In the Analysis phase, curriculum analysis and needs analysis were conducted. Curriculum analysis was carried out by reviewing the study program curriculum, course syllabus, and semester lesson plans, as well as interviewing numerical methods lecturers to identify course learning outcomes and key indicators related to numerical methods and mathematical creative thinking (Doli Nasution et al., 2017). Needs analysis focused on identifying students' difficulties in understanding numerical methods concepts and the

absence of attractive Python-assisted teaching materials, which was conducted through interviews with lecturers and a review of previous learning documentation.

In the Design phase, the structure and components of the module were determined and organized systematically. Learning objectives, content organization, and problem-based activities were specified based on course learning outcomes and indicators of mathematical creative thinking (Akhsani et al., 2025; Nurhayati, 2017). The module design included orientation sections, explanations of concepts and procedures, worked examples, practice exercises, problem-based tasks integrating Python programming, evaluations, and answer keys, as well as visual and layout elements to enhance readability and attractiveness (Pannen, 2001; Prastowo, 2011). Relevant references on numerical methods, Python programming, teaching materials development, and mathematical creative thinking were selected to support the preparation of the module content (Doli Nasution et al., 2017; Alfarizi et al., 2023).

In the Development phase, a draft of the Python-assisted numerical methods module based on problem-based learning was produced and then subjected to expert validation. Three expert validators—consisting of a media expert, a content expert, and an education expert—assessed the module using a Likert-scale validation instrument with five response categories from very poor to very good (Riduwan, 2009). The instrument items were grouped into several aspects, including content accuracy and completeness, alignment with learning outcomes, clarity of instructions and language, integration of problem-based learning and Python tasks, and visual design (Nurhayati, 2017; Putra et al., 2024). The percentage score for each validator was calculated by comparing the obtained raw score with the ideal score and then converting it into a percentage, which was interpreted using criteria adapted from Riduwan (2009), where 0–20% is very weak, 20–40% weak, 40–60% medium, 60–80% strong, and 80–100% very strong. After revisions based on expert suggestions, a small-group trial was conducted with students who attended the numerical methods course to obtain their responses regarding the practicality and attractiveness of the module using a similar Likert-scale questionnaire.

RESULTS AND DISCUSSION

The main product of this research was a Python-assisted numerical methods teaching module that adopts a problem-based learning model and is designed to support students'

mathematical creative thinking abilities. The module was developed based on the ADDIE model and includes several components, namely an attractive cover, table of contents, concept maps, orientation sections, explanations of concepts and procedures, worked examples, practice exercises, evaluations, and answer keys for each learning activity (Muruganantham, 2015; Nurhayati, 2017). Each chapter presents numerical methods topics such as nonlinear equations, systems of linear equations, interpolation, numerical differentiation and integration, and ordinary differential equations, which are integrated with Python programming tasks (Doli Nasution et al., 2017; Wulan et al., 2017). Problem-based activities are embedded in the form of contextual problems and open or semi-open tasks that require students to select, implement, and compare several numerical techniques using Python scripts that can be modified according to the given situations (Akhsani et al., 2025; Alfarizi et al., 2023).

The feasibility of the developed module was evaluated through expert validation and a small-group trial. Three expert validators assessed the module using a Likert-scale instrument and the analysis results show that the module obtained an average score of 75.26%, which falls into the “Strong” category, indicating that the module is feasible to be used as a teaching material in numerical methods lectures with some suggestions for refinement (Riduwan, 2009). This finding is in line with various development studies that report feasibility or validity percentages in the range of 70%–90% for mathematics modules designed with systematic models such as ADDIE, which are categorized as valid or highly valid (Muruganantham, 2015; Nurhayati, 2017). For example, Azizah, Asiya, and Wahyuni (2025) reported that a mathematics module on measurement using a digital flipbook achieved feasibility percentages above 80% and was classified as feasible for classroom implementation. Similarly, Hutapea and Manurung (2022) developed mathematics learning modules using project-based learning models and obtained feasibility values in the “feasible” to “highly feasible” categories, as indicated by high validation and response scores (Hutapea & Manurung, 2022). Putra, Taufik, and Nadlifah (2024) also found that mathematics learning media based on MATLAB GUI developed with the ADDIE model achieved high validity and practicality indicators (Putra et al., 2024). These similarities strengthen the interpretation that the validity score of 75.26% places the developed numerical methods module in a reasonable feasibility range compared to other mathematics modules reported in the literature.

In addition to expert validation, the small-group trial showed that students' responses to the module reached an average of 92.3%, which is categorized as "Very Strong", indicating very high practicality and positive student perceptions. Students reported that the explanations, examples, practice questions, and Python-based activities helped them understand the material and supported independent learning. High practicality and positive responses are also found in other studies that developed PBL-based and electronic modules, where feasibility and practicality percentages often reached the "very valid" and "very practical" categories (Nurhayati, 2017; Tambunan & Tambunan, 2022; Reski et al., 2021). Raviqah, Rohman, and Lestari (2023), for instance, reported that an electronic module based on problem-based learning was very valid and very practical from both practitioner and student perspectives and was effective in improving students' creative thinking skills (Raviqah et al., 2023). Similar patterns are observed in studies that develop PBL modules for improving critical and creative mathematical thinking, which consistently obtain high validity indices and very positive student responses (Herlistiyanti et al., 2025; Kurniati & Sutiarso, 2021; Lubis, 2023; Zulkarnaen et al., 2022). Therefore, the very strong student response to the developed module is consistent with previous findings that well-designed PBL-based teaching materials tend to be perceived as attractive, useful, and supportive of independent learning.

From the perspective of mathematical creative thinking, the design of problem-based activities and Python programming tasks in the module provides opportunities for students to practice key creativity indicators such as fluency, flexibility, and originality. Through open or semi-open problems, students are encouraged to generate multiple solution ideas, try different numerical methods, and compare the resulting approximations and errors, which support fluency and flexibility in mathematical creative thinking (Akhsani et al., 2025; Doli Nasution et al., 2017). This is supported by empirical evidence that PBL and open-ended approaches have significant effects on students' mathematical creative thinking abilities across various educational levels, as reported in several experimental and meta-analysis studies (Herlistiyanti et al., 2025; Kurniati & Sutiarso, 2021; Lubis, 2023; Zulkarnaen et al., 2022). At the same time, research on the use of programming tools in numerical analysis courses shows that Python-based tasks can increase student engagement, provide immediate feedback, and facilitate exploration of different numerical methods, thereby supporting deeper conceptual understanding and creative experimentation (Gwynllyw et al., 2020;

Alfarizi et al., 2023). The combination of PBL and Python in the developed module is therefore consistent with the direction of previous studies that integrate problem-based learning and technology to foster higher-order mathematical thinking, including creative and critical thinking (Febrianti et al., 2021; Nurhayati, 2017). Although the present study has not yet measured changes in students' mathematical creative thinking abilities empirically, the strong validity and very strong student responses, coupled with the alignment with these previous findings, indicate that the developed module has promising potential to support the development of mathematical creative thinking in numerical methods learning.

When compared with the previously used teaching materials, the developed module offers several notable improvements. The previous module was characterized by brief explanations, limited examples and exercises, and a less attractive visual appearance, which tended to make students less motivated to read and study independently. In contrast, the new module presents more complete material explanations, more representative and varied examples, and sufficient practice exercises and evaluations, thus providing better support for independent learning (Nurhayati, 2017; Tambunan & Tambunan, 2022; Reski et al., 2021). The module also includes motivational statements and visually appealing layouts, which are expected to enhance students' engagement and persistence in learning numerical methods. These improvements, supported by strong validity and very strong student responses, indicate that the developed module can be considered a feasible and practical alternative teaching material for numerical methods learning.

However, the findings of this study should be interpreted in light of several limitations. The development process was limited to the first three phases of the ADDIE model, namely Analysis, Design, and Development, so the research only covered aspects of feasibility (validity and practicality) without including formal effectiveness testing on learning outcomes and mathematical creative thinking ability (Muruganantham, 2015). In addition, the scope of the module content is still restricted to several main topics in the numerical methods course, and the small-group trial involved a limited number of students. These limitations open opportunities for future research to conduct broader implementation and experimental or quasi-experimental studies that systematically measure the impact of the module on students' mathematical creative thinking abilities and extend the module content to other

numerical methods topics (Herlistiyanti et al., 2025; Kurniati & Sutiarso, 2021; Zulkarnaen et al., 2022).

CONCLUSION

The study developed Python-assisted numerical methods teaching materials in the form of a problem-based learning module and examined their feasibility through expert validation and a small-group trial. Using an R&D approach with the ADDIE model limited to the Analysis, Design, and Development phases, the research produced a structured module that integrates problem-based activities and Python programming tasks within explanations, worked examples, practice exercises, and evaluations. Expert validation yielded an average score of 75.26% in the “Strong” category, while student responses reached 92.3% in the “Very Strong” category, indicating that the module is valid and highly practical for numerical methods learning. Based on its design characteristics and alignment with previous findings on problem-based learning and technology integration, the module has promising potential to support the development of students’ mathematical creative thinking abilities, although this potential still needs to be confirmed through future experimental or quasi-experimental studies that directly measure learning outcomes and creative thinking.

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