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The Effectiveness Of Students' Worksheets In Advancing Mathematical Understanding: A Case Study In Partial Differential Equation Class

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Abstract:
Background*: This study aims to determine the effectiveness of student worksheets in improving mathematical understanding in partial differential equation classes. To date, student worksheets are recognized as pedagogical tools designed to encourage active student engagement, guide students through the problem-solving process, and bridge the gap between theoretical concepts and practical applications, which students have traditionally found difficult.*
Materials and Methods*: This study uses a case study approach involving undergraduate mathematics students in Indonesia who are taking partial differential equations courses at Universitas Negeri Surabaya. Data for this study were collected through assessments, classroom observations, and student feedback questionnaires.*
Results*: The results of the study show that the use of student worksheets is proven to be much more effective than traditional lectures. These worksheets not only help students better understand concepts and improve their problem-solving skills but also improve their overall academic performance. Several students also reported that the structured guidance provided by the student worksheets greatly helped them organize the teaching and learning process, clarified complex concepts, and made them feel more confident when facing mathematical problems.*
Conclusion: *From these results, it can be concluded that the use of student worksheets in the lecture process can support individual learning and encourage students to collaborate with their peers. This study also highlights the pedagogical value of student worksheets as a low-cost teaching strategy that has a tremendous impact on advanced mathematics education. Therefore, based on the results of this study, teaching staff, especially lecturers in higher education, are encouraged to integrate student worksheets into their teaching practices because these worksheets can be used to improve student understanding, especially in challenging mathematics courses such as partial differential equations.*
Key Word: *worksheet, mathematical understanding*

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I. Introduction

Based on the researcher's experience in teaching the Partial Differential Equations course over the past few years, many students feel that this course is not easy to learn and poses a challenge for many undergraduate mathematics students. Although this course is a fundamental tool in science and engineering because it can help in understanding real-life phenomena such as heat transfer and wave motion, students still find it difficult to master this course. These difficulties are not only related to complex calculations, but also learning how to think abstractly and apply theoretical concepts to real-world problems. This is one of the reasons why lecturers who teach this course often find it difficult to help students connect classroom theory with practical problem solving in everyday life.

Another main reason why students have difficulty understanding the material taught in Partial Differential Equations classes is that they struggle to follow the correct algorithm for solving each problem given. Students often have difficulty classifying equations, applying the appropriate solution techniques step by step, and mastering integration methods.

Through this study, the research team proposed a method that can be used to overcome these persistent and challenging difficulties, namely by developing structured student worksheets, which offer a promising alternative solution, as they can provide systematic guidance and support in understanding the solution process more effectively. Student worksheets are an excellent teaching tool and have proven to be invaluable in mathematics education (Basuki & Wijaya, 2018; Lestari et al., 2023; Tumangger et al., 2024). Unlike traditional lectures, worksheets engage students actively in the learning process. These worksheets offer structured exercises and step-by-step guidance that allow students to test their understanding directly. By solving problems

independently or with classmates, students can directly build a deeper understanding and develop strong critical thinking skills(Bivins, 1993; Riccomini & Morano, 2019).

This worksheet is very important because it not only helps students understand concepts but also helps them become more independent learners. Students can organise their thoughts better, identify their difficulties, and feel more confident in solving complex mathematical problems when guided through carefully planned tasks (Henningsen & Stein, 1997; Lerch, 2004; Tachie, 2019). This is in line with the concept of active learning, where students are able to build knowledge through practice, not just by listening. In fact, many studies also show that the use of worksheets can improve grades, enhance problem-solving skills, and help students remember information for longer (Buffalari, 2022; Melawati et al., 2022; Nelson & Crow, 2014).

This worksheet is even more important in complex subjects such as Partial Differential Equations lectures, where students are required to perform numerous and gradual reasoning processes, which can ultimately overwhelm them. Worksheets help by breaking down these complex processes into smaller steps that are easier to manage or solve (Sujatmika & Wibowo, 2020; VanGundy, 2004). This approach facilitates understanding and helps students see how different mathematical techniques are logically connected.

These student worksheets are also very useful in connecting abstract theory with real-world problems (Fauziah & Nurita, 2019; Marshel et al., 2021; Pelemeniano & Siega, 2023). By including exercises on heat conduction or wave motion, a lecturer can show students how the complex mathematics they are learning can be applied in everyday situations. This helps students understand the practical value of partial differential equations and makes the course more relevant and interesting. This kind of contextualization has increased student motivation and engagement, as students tend to value learning when they understand its practical significance.

Given these advantages, it is essential to examine the effectiveness of students' worksheets in advance of students' understanding in Partial Differential Equations courses. While previous research has broadly documented worksheets' benefits in mathematics education, fewer studies have explicitly focused on advanced topics such as Partial Differential Equations Investigating their role in this context will provide insights into effective teaching strategies and contribute to improving mathematics education practices more generally.

This study examines whether using worksheets can help students better understand and succeed in a Partial Differential Equations class. By looking at how these worksheets improve conceptual understanding, problem-solving skills, and overall grades, the research hopes to show how valuable they are for teaching advanced math. Ultimately, the goal is to give lecturers some practical tips on how to help students learn more effectively in this challenging subject.

II. Literature Review

Mathematics learning at the university level often presents significant challenges for students, particularly in courses such as Partial Differential Equations (Mohammed, 2019). These difficulties usually arise due to the complexity of the solution process, which begins with classifying equations, determining boundary conditions, and selecting the appropriate transformation method. To bridge the gap between abstract theory and learning practice, the use of student worksheets has become one of the strategies that continues to be developed. Worksheets are considered effective as a scaffolding medium that helps students organize the steps of the solution systematically, thereby minimizing the cognitive load (Borchers et al., 2025).

Recent studies indicate that worksheets designed using problem-based learning and interactive case-based learning approaches can improve numeracy, conceptual understanding, and problem-solving skills. This is true not only at secondary school level but also at university level, including in Partial Differential Equations classes. The active involvement of students in completing worksheets has been proven to strengthen critical and reflective thinking processes, while also increasing confidence in material that is considered difficult (Rahmawati et al., 2025).

From a pedagogical perspective, worksheets serve as scaffolding tools that provide temporary support so that students can develop independence in learning. Recent studies also show that high-level scaffolding is more effective in strengthening conceptual understanding than strategies with low scaffolding or complete freedom (Hofer & Reinhold, 2025). In the context of Partial Differential Equations, this scaffolding is important for linking prerequisite knowledge such as calculus and Ordinary Differential Equations with the ability to solve Partial Differential Equations using the separation of variables or Fourier transformation methods.

In addition to benefiting students, the use of worksheets also helps lecturers to map out the difficulties experienced by students. This information can be used as a basis for evaluating learning and improving teaching strategies. Thus, worksheets not only serve as an instrument for evaluating students, but also as a means of reflection for lecturers. Their effectiveness lies in their ability to provide more humanistic, interactive, and adaptive learning to the needs of students.

III. Research Method

This study investigates the effectiveness of students' worksheets in advancing mathematical understanding. The study began with the development of worksheets based on the ADDIE design (Putri A. N., 2022; Sari, 2024). The systematic implementation of the development model is as follows.

Analysis

The main objective of the analysis stage is to identify possible causes of defects in the work. In this case, it shows whether a lack of knowledge and skills causes the performance gap, then suggests training options and develops a statement of intent. This stage also involves data collection for learning design. This analysis activity can be used to determine how the development process is carried out. This analysis activity will take the form of observation, to describe the problems that occur, to find out the conditions of the students, to determine the appropriate learning materials, and to find out the extent of the students' skills in the subject.

Design

In the ADDIE development model, the second step is design. In this step, clarification of the designed learning program is required so that the program can achieve the set learning objectives. There are four reference frameworks at this stage.

a. For whom is the learning designed?
b. What abilities are desired for learning?
c. How can the basic material or skills be learned well?
d. How do researchers determine the level of mastery of the lessons that have been achieved?

At this stage, researchers carry out a systematic process that begins with designing the concept and content of the product. The design is written for each product's content. Instructions for implementing the design or manufacturing the product should be written clearly and in detail. This stage is still conceptual and will underpin the development process in the next stage. Researchers must create a new work design to produce a new work system. This latest work design is developed based on an assessment of the old work system, so that weaknesses in the system can be identified. In addition, researchers must also conduct research on other units whose work systems are considered good.

Development

Development in the ADDIE development research model involves the realization of the product design that was previously created. A conceptual framework for applying the new product was developed in the previous stage. This conceptual framework is then realized as a product ready for implementation. At this stage, it is also necessary to create instruments to measure product performance.

Implementation

The fourth stage is implementation. The development results are applied in learning to determine their effect on the quality of education, including the effectiveness, attractiveness, and efficiency of learning. The development product design needs to be tested in the field to obtain an overview of learning effectiveness, attractiveness, and efficiency. Effectiveness relates to how the development product can achieve the expected objectives or competencies. Attractiveness relates to how the development product can create an enjoyable, challenging learning atmosphere that motivates students to learn. Efficiency is using all resources, such as funds, time, and energy, to achieve the desired objectives.

Evaluation

It states that this evaluation assesses learning effectiveness and identifies improvement areas. Assessment can be conducted in two forms: formative assessment and summative assessment. Formative assessment is conducted during the learning process to provide constructive feedback, while summative assessment is conducted after the learning process to assess the achievement of objectives.

IV. Discussion

Based on the findings obtained from this study, there is convincing evidence that the integration of student worksheets in Partial Differential Equations courses significantly improves students' mathematical understanding and performance. In addition, worksheets create a more interactive and student-centred learning environment compared to traditional lecture approaches. This improvement is evident not only in test scores but also in the way students approach problem-solving tasks. Several students reported that the use of worksheets helped them organise their thoughts, reduce mental load, and solve problems step by step, rather than feeling overwhelmed by the complexity of the material. These findings also confirm the potential of structured worksheets as an effective pedagogical intervention in advanced mathematics courses.

The main result obtained from this study is an increase in conceptual understanding. Students who used worksheets demonstrated better ability in correctly classifying partial differential equations and applying appropriate solution methods. This finding also supports other studies that worksheets are an excellent tool for helping students understand the 'how' and 'why' behind mathematical concepts. The step-by-step structure of the worksheets helps students follow a logical path, which makes the abstract reasoning in mathematics much easier to understand. This also indirectly serves as a valuable guide for problems that require multi-step methods such as variable separation and Fourier series expansion.

Another result obtained from this study was an increase in students' confidence and independence. Worksheets taught students to break down large and complex problems into smaller, more manageable parts. This transparent process helps students eliminate feelings of frustration and makes them more confident when facing problems in partial differential equation lectures. Students in this study also said that the worksheets provided them with a roadmap for solving problems, which made them more willing to try exercises that they might have avoided before.

In addition, this study also found that collaboration and peer learning played a significant role. During worksheet sessions, students worked together, shared strategies, and learned from one another. The social aspect of this learning helped deepen their understanding and improve their critical thinking skills. Although the worksheets were intended for individual use, their adaptability for group work was a significant advantage. These results are consistent with other studies showing that student interaction improves understanding.

However, several challenges still arise in this study. Although worksheets are very useful for guiding students through structured problems, some students still experience difficulties with new or unusual Partial Differential Equations problems. This shows that worksheets are excellent for developing procedural skills, but there is still the possibility of ineffectiveness in developing higher-level transfer skills. To overcome this, we can combine worksheets with other methods, such as project-based learning or real-world modelling, to encourage students to apply what they have learned in new situations.

The findings obtained from this study have important implications for mathematics lecturers. These findings indicate that it is very important to design worksheets that provide guidance and allow for independent exploration. Worksheets that are too rigid can inhibit creativity, while those that are too open may not provide sufficient support. One key is to find the right balance, so that students can understand the basics of solving partial differential equations and learn to apply them independently. These findings also suggest that relatively low-cost interventions such as worksheets can result in significant improvements in student learning, making them an affordable tool for institutions with limited resourcesThis study confirms that student worksheets are a highly effective and practical tool for teaching a complex subject like Partial Differential Equations. They successfully improve students' understanding, build confidence, and encourage peer collaboration. While they might need to be paired with other methods to develop advanced problem-solving skills fully, their value is clear. For the future, researchers should explore how different types of worksheets have impact learning in Partial Differential Equations and other advanced math classes for instance like those based on inquiry, real-world applications, or technology. It would also be beneficial to conduct long-term studies to see if the skills gained from using these worksheets translate into better performance in future courses or professional careers.

V. Conclusion

This study shows that student worksheets are highly effective in helping students understand Partial Differential Equations. By giving them structured, step-by-step guidance, the worksheets enabled students to classify equations better, use the proper solution methods, and improve their integration skills. The findings also suggest that worksheets don't just help with following procedures; they also build confidence and promote active learning, both independently and with peers.

While worksheets are great, this study shows they can't solve all problems, especially when students face new or very complex Partial Differential Equations questions. Worksheets should be combined with other methods, like project-based tasks, real-world applications, and computational tools, to get the most out of them. These strategies can help broaden students' learning and develop their advanced problem-solving skills.

Ultimately, using student worksheets is a practical and low-cost way to improve math comprehension in one of the toughest areas of undergraduate studies. Future studies should investigate how different worksheet designs, particularly those enhanced by inquiry-based and technology-supported methods, can improve learning outcomes and ensure students are well-prepared to apply Partial Differential Equations in academic and professional contexts.

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