The Effectiveness of the STEM-based Differentiation Learning Model on Merdeka Curriculum Learning Outcomes

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Abstract

This study aims to determine the effectiveness of the STEM-based differentiation learning model on the results of independent curriculum learning. This type of research is quantitative research with a meta-analysis approach. This research data comes from 10 national journals published from 2021-2024. Search research data through the mendeley, google scholar, Wiley and Researchgate databases. The data collection technique is purposive sampling. The criteria for the data included in the meta-analysis are research published in the last 3 years 2021-2024; Research must be related to STEM-based differentiation learning on student learning outcomes in the independent curriculum, research must be open access, research comes from indexed journals Science Technology Index (SINTA) and Scopus and research reports complete data to calculate effect size values. Data analysis is quantitative data analysis by calculating the effect size value of each data with the help of the JAMOVI application. The results of the study concluded that STEM-based differentiation learning had a positive effect on the independent curriculum with an average effect size value of 1.06. These findings provide important information for teachers implementing STEM-based differentiated learning in schools.

Keywords:Differentiation Teachings; STEM; Learning Outcomes, Independent Curriculum

Introduction

Curriculum Merdeka is an educational concept that aims to provide freedom and flexibility to students in exploring students' interests, talents, and potentials (Munte, 2022; Purwasih et al., 2021). The concept of an independent curriculum, students are encouraged to take a more active role in the learning process, by allowing them to choose subjects, projects, and extracurricular activities that suit students' interests (Zainuri, 2022). In addition, the Merdeka Curriculum also emphasizes the development of 21st century skills such as creativity, problem solving, critical thinking, and collaboration, thus preparing students to better face the challenges of the modern world (Intiana et al., 2023; Suryono et al., 2023).

The implementation of the Merdeka Curriculum has great potential to improve the quality of education by enabling better adjustment to the individual needs of

students (Aliyyah et al., 2023). By giving students the freedom to explore their own interests, they can engage more deeply in the learning process that improves student motivation and academic outcomes (Onwumere et al., 2021). In addition, this approach can also help reduce excessive learning pressure, as students can focus on their areas of interest and feel more motivated in achieving their academic and career goals. Thus, Curriculum Merdeka is not only about giving freedom to students, but also about creating an educational environment that is inclusive, responsive, and allows each individual to develop optimally (Chamisijatin et al., 2023; Utomo et al., 2023).

In the implementation of the independent curriculum, there are many problems.

One of the critical issues in the implementation of the Independent Curriculum is the challenge of ensuring that the flexibility afforded to students does not come at the expense of nationally established academic standards and established educational goals (Thompson & Atkinson, 2010; Santosa & Yulianti, 2020). In an environment where students have the freedom to determine their own learning path, the question arises of how to ensure that each individual acquires the necessary knowledge and skills according to the expected standards, while maintaining freedom and diversity in the student learning experience (Petrie & Darragh, 2013; Fradila et al., 2021; Elfira et al., 2023). This issue is challenging in the context of evaluation and assessment, where a holistic and equitable approach is needed to measure student achievement that considers the diversity of learning paths they take. Thus, this problem requires creative thinking and careful strategy to achieve a balance between flexibility and standards in the Merdeka Curriculum. Therefore, there is a need for learning that is able to encourage the quality of student learning results.

Differentiated Learning is learning that aims to accommodate the individual needs of students in a more effective way than conventional learning approaches (Jager, 2013). This approach recognizes that every student has different learning styles, needs, and interests, so teachers must use a variety of tailored learning strategies to meet those needs. With differentiation, teachers can provide learning materials tailored to the level of student understanding (Brodersen & Melluzzo, 2022), provide additional challenges for students who need them, and provide extra support for students who are struggling. This not only helps increase student participation and motivation, but also allows them to reach their maximum potential in learning.

However, the implementation of differentiated learning can also pose some challenges. One is to ensure that all students get equal attention and feel valued despite the difference in their ability levels. Teachers need to ensure that no student is forgotten or feels marginalized in the learning process. In addition, there are also logistical challenges in planning and implementing differentiated learning, especially in large classes with students who have very diverse needs and interests. Teachers should have extensive skills and knowledge of different learning strategies as well as the availability of resources that support the effective implementation of differentiated learning (Aguanda et al., 2023). By addressing these challenges, differentiated learning can be a very effective tool to ensure that every student gets learning that matches the needs and potential of students (Tahiri et al., 2017).

Research on STEM-based differentiation learning models in the context of the Independent Curriculum faces a number of interesting problems to be investigated in depth. One of the main issues that can be the focus of research is the challenge of implementing an effective differentiation approach in a classroom environment that allows students to choose their own curriculum. This raises the question of how teachers can effectively tailor STEM learning to students' individual needs and interests without compromising nationally agreed curriculum coverage (Suryati et al., 2023). In addition, research can also pay attention to how STEM-based differentiation learning models affect student motivation and participation, as well as whether there are differences in learning outcomes between students who follow this model and students who follow conventional learning approaches (Rahayu et al., 2022). In addition, aspects of assessment and evaluation of STEM-based learning in the context of the Independent Curriculum are also an important concern, including how to measure the achievement of STEM competencies and 21st century skills in this learning model. By investigating these issues, research can provide valuable insights to improve the effectiveness of implementation of STEM-based differentiation learning models in the Independent Curriculum and provide a solid foundation for the development of more inclusive and responsive STEM pedagogy (Forbes, 2013).

Research before by (Meyad et al., 2014) Differentiated learning has a significant influence on student learning motivation. Research by Marlima et al., (2023) Diffrencing learning can increase students' active learning in inclusion classes. Mostly, there is little research on differentiated learning that illustrates the effect of the size of STEM-based differentiated learning on student learning outcomes. Therefore, this study aims at the effectiveness of the STEM-based differentiation learning model on the results of independent curriculum learning.

Research Methods

This type of research is quantitative research with a meta-analysis approach. Meta-analysis is a type of research that collects funds to analyze previous research quantitatively to come to a conclusion (Tamur et al., 2020; Chamdani et al., 2022; Oktarina et al., 2021; Zulyusri et al.,, 2023; Suharyat et al., 2023; Suparman et al., 2021). This research data comes from 10 national journals published from 2021-2024. Search research data through the mendeley, google scholar, Wiley and Researchgate databases. The data collection technique is purposive sampling. The criteria for the data included in the meta-analysis are research published in the last 3 years 2021-2024; Research must be related to STEM-based differentiation learning on student learning outcomes in the independent curriculum, research must be open access, research comes from indexed journals Science Technology Index (SINTA) and Scopus and research reports complete data to calculate effect size values. Data analysis is quantitative data analysis by calculating the effect size value of each data with the help of the JAMOVI application. Furthermore, the criteria for effect size values can be seen in Table 1.

Table 1. Effect Size Value Criteria

Effect Size Value	Criteria
$0.00 \leq ES \leq 0.20$	Low
$0.20 \leq ES \leq 0.80$	Medium
$ES \geq 0.80$	High

Source:(Cohen et al., 2007; Nurtamam et al., 2023); Rahman et a., 2023)

Results and Discussion

From the search results from Mendeley, Google Scholar, Wiley and Researchgate related to STEM-based differentiation learning on student learning outcomes in the independent curriculum of 290 journals, but only 10 journals met the predetermined inclusion criteria. The data filtering process through the PRISMA 2020 model consists of identification, screening, eligibility and included. Furthermore, those who have met the inclusion criteria are calculated effect size values which can be seen in Table 2.

Table 2. Effect size value

Study Code	Year	N	Effect Size	Effect Size Criteria
J1	2023	23	0.77	Medium
J2	2023	46	1.18	High
J3	2024	82	0.93	High
J4	2021	90	2.10	High
J5	2022	55	1.08	High
J6	2022	72	0.62	Medium
J7	2024	30	0.58	Medium
J8	2023	42	0.95	High
J9	2023	48	1.19	High
J10	2023	52	1.20	High
Average effect size			1.06	High

Based on Table 2, the effect size values of 10 studies ranged from 0.62 to 2.10. Furthermore, the average value of the effect is 1.06 with high criteria. These results show that STEM-based differentiated learning has a significant effect on student learning outcomes in the independent curriculum. This research is in line with (Fakhrudin et al., 2023) The application of STEM-based differentiation learning has a positive influence on learning outcomes in the independent curriculum. (Prasetyo et

al., 2023) STEM-based differentiated learning can foster students' critical thinking skills, thus supporting student learning outcomes. In this approach, differentiation allows teachers to tailor learning according to students' individual needs and interests. Unlike conventional learning approaches that are often one-size-fits-all, differentiation models allow students with varying levels of ability to develop according to their individual potential (Mulbar et al., 2018).

One of the important findings of this study is that STEM-based differentiated learning models are able to increase student learning motivation. By introducing scientific concepts through practical and relevant applications in everyday life, students feel more engaged and enthusiastic about learning (Mertanti et al., 2022). This also indirectly has an impact on improving learning outcomes, because students are more motivated to understand the material more deeply.

In addition, research has also shown that STEM-based differentiation learning models help in addressing learning outcome disparities between students. With an approach that adapts learning materials and methods according to individual needs, students with different backgrounds and abilities can achieve academic success. This is in line with the spirit of the Independent Curriculum which prioritizes inclusivity and equality in education.

Furthermore, this research also provides important insights for the development of curricula that are more adaptive and responsive to future needs. Through the integration of STEM in learning differentiation, students are not only equipped with knowledge and skills relevant to technological and scientific developments, but are also empowered to become independent and creative learners (Hidayati et al., 2024). Thus, the STEM-based differentiation learning model can be considered as one of the pillars in the implementation of the Independent Curriculum which is oriented towards holistic and sustainable learning outcomes. In addition, this study suggests that STEM-based differentiated learning models can promote inclusivity and equity in education (Vennix et al., 2017). By tailoring the approach to learning to individual needs, this model opens the door to academic success for students with diverse backgrounds. This is in line with the spirit of the Independent Curriculum which emphasizes increasing access and equitable learning opportunities for all students, without exception (Fauzan et al., 2023).

Conclusion

From this study, it can be concluded that STEM-based differentiation learning has a positive effect on the independent curriculum with an average effect size value of 1.06. These findings provide important information for teachers implementing

STEM-based differentiated learning in schools. This model not only enhances students' understanding of STEM concepts, but also strengthens their critical thinking, creativity, and collaboration skills. In addition, differentiation allows accommodating individual students' needs and interests, as well as promoting inclusivity and equity in education. The importance of support and professional development for teachers in applying this model is also highlighted, along with the need for a holistic evaluation of its effectiveness. Thus, the STEM-based differentiation learning model has great potential to support the vision of the Independent Curriculum.

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