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The Influence of STEM Learning Models on the Learning Outcomes of Modeling and Simulation Mediated by 21st Century Skills and Leadership Competence

Muhammad Yassir[1], Purnamawati[2], Hasanah Nur[3]
[1]*Sistem dan Teknologi Informasi, Institut Teknologi dan Bisnis Nobel Indonesia, Indonesia*
[2,3]*Pendidikan Vokasi Keteknikan, Universitas Negeri Makassar*

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Corresponding Author:

Muhammad Yassir

Email: myassir669@gmail.com

ABSTRAK

Penelitian ini bertujuan untuk mengetahui Pengaruh Model Pembelajaran STEM terhadap Hasil Belajar Pemodelan dan Simulasi yang Dimediasi oleh Keterampilan Abad 21 dan Kompetensi Kepemimpinan. Penelitian ini merupakan penelitian *ex post facto*, yaitu penelitian yang dilakukan setelah peristiwa atau kondisi tertentu terjadi. Pengumpulan data dalam penelitian ini menggunakan kuesioner untuk variabel Pembelajaran STEM, Keterampilan Abad 21, Kompetensi Kepemimpinan, dan Hasil Belajar. Validitas dari keempat instrumen tersebut diuji dengan menggunakan uji korelasi *Pearson Product Moment*, dan reliabilitasnya dinilai dengan menggunakan *Cronbach's Alpha*. Selanjutnya, data yang terkumpul dianalisis dengan menggunakan statistik deskriptif dan inferensial (Path Analysis). Penggunaan Analisis Jalur memberikan keuntungan dalam mengeksplorasi hubungan antar variabel yang kompleks dan memfasilitasi pengujian empiris model konseptual. Temuan penelitian menunjukkan bahwa; (1) Terdapat pengaruh langsung yang positif dan signifikan dari pembelajaran STEM terhadap hasil belajar, keterampilan abad ke-21, dan kompetensi kepemimpinan, (2) Keterampilan abad ke-21 dan kompetensi kepemimpinan masing-masing juga memiliki pengaruh langsung yang positif dan signifikan terhadap hasil belajar, dan (3) Pembelajaran STEM memiliki pengaruh positif dan signifikan terhadap hasil belajar yang dimediasi oleh Keterampilan Abad ke-21 dan kompetensi kepemimpinan.

ABSTRACT

This study aims to investigate the Influence of STEM Learning Models on the Learning Outcomes of Modeling and Simulation Mediated by 21st Century Skills and Leadership Competence. This research is an ex post facto study, conducted after certain events or conditions have occurred. Data collection in this study utilized questionnaires for STEM Learning, 21st Century Skills, Leadership Competence, and Learning Outcomes variables. The validity of these four instruments was tested using the Pearson product-moment correlation test, and reliability was assessed using Cronbach's Alpha. Subsequently, the collected data were analyzed using descriptive and inferential statistics (Path Analysis). The use of Path Analysis provides advantages in exploring relationships among complex variables and facilitates the empirical testing of conceptual models. The research findings indicate that; (1) There is a direct positive and significant influence of STEM learning on learning outcomes, 21st-century skills, and leadership competence, (2) 21st Century Skills and leadership competence each also have a direct positive and significant influence on learning outcomes, and (3) STEM learning has a positive and significant influence on learning outcomes mediated by 21st Century Skills and leadership competence.

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INTRODUCTION

STEM (Science, Technology, Engineering, and Mathematics) learning is an educational approach that emphasizes the integration of these four disciplines. This concept is designed to provide a holistic, contextual, and relevant learning experience for students. STEM learning goes beyond understanding scientific concepts; it integrates the application of technology, engineering, and mathematics into everyday life. In STEM learning, students are invited to think critically, solve problems, and collaborate. Educators play the role of facilitators guiding students in exploration and scientific discovery through challenging projects (Nugroho et al., 2019; Setiawan et al., 2020; SUWARDI, 2021).

One key characteristic of STEM learning is its interdisciplinary approach. Students don't just study each subject separately; they explore relationships and connections between the four disciplines. For example, they can solve real-world problems by designing and building simple technology projects, analyze data using mathematical concepts, and understand the scientific principles behind the technology they develop (Khairani et al., 2018; Lestari, 2019). Additionally, STEM learning emphasizes the application of knowledge in real-life situations. Students are encouraged to make connections between theory and application, enabling them to see the relevance and significance of what they learn in their daily lives. This can provide additional motivation for students as they realize the direct impact of their learning on the real world. STEM learning is not just a teaching method but also an educational philosophy that stimulates students' curiosity and exploration. Through this approach, it is expected that students can develop the skills needed for success in the increasingly complex and technological global era ((Yassir et al., 2022)Fathoni et al., 2020; Gok, 2021).

STEM learning has a tremendous impact on the development of essential skills to face the complexities of the 21st century. Through this approach, students not only explore knowledge in various disciplines but also sharpen crucial skills and attitudes in this ever-changing world. One of the most prominent influences of STEM learning is the development of critical thinking skills. Students are encouraged to question, analyze, and critically evaluate information. They learn to identify problems, design solutions, and make informed decisions. These skills help students become not only intelligent information consumers but also active contributors to the knowledge discovery process (Kasuma et al., 2022; Muttaqiin, 2023).

Furthermore, STEM learning also stimulates students' creativity. In solving projects that require creative thinking, students are given space to imagine, experiment, and find innovative solutions. This creativity is the foundation for innovation, a driving force in various sectors, including technology, business, and the arts. Collaboration is also a key aspect of STEM learning. Students not only learn to work in teams but also share ideas and knowledge

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with their peers (Rahmawati et al., 2022; Sandi, 2021). This collaborative ability builds social, communication, and leadership skills, which are crucial in the modern interconnected work environment. STEM learning also provides a strong foundation in technology literacy. Students not only use technology as a tool but also understand the basics of technology, algorithms, and programming. This technological literacy helps them become more adaptive to the ever-evolving changes and demands of technology (N.L.P.S. Murthi et al., 2022; Zahirah & Sulistina, 2023).

The problem-solving skills developed through STEM learning also have a significant impact. Students learn to see problems as opportunities, not obstacles. They are trained to design effective and efficient solution strategies, contributing to adaptability and innovation, the foundation of success in the 21st century (Jannah et al., 2022; Ramli et al., 2023; Rusminati & Juniarso, 2023). Thus, the influence of STEM on 21st-century skills not only transforms the way students understand and apply scientific and technological knowledge but also shapes individuals who are creative, critical thinkers, collaborative, technologically literate, and ready to face the complex challenges of the future.

STEM learning has a significant positive impact on the leadership development of students in the learning process. Through the STEM approach, students are not only directed to understand scientific concepts but also developed as leaders in a dynamic learning environment. STEM learning provides students with opportunities to take an active role in the learning process. They are not just knowledge receivers but knowledge creators. By having more control over projects or experiments, students learn to take initiative, make decisions, and plan steps to achieve their goals. STEM instills problem-solving skills in students. Faced with challenges of complex projects, students become leaders in identifying problems, analyzing situations, and designing solutions. These skills are highly relevant in leadership, where the ability to address problems and offer effective solutions is a crucial foundation (Öztop, 2023; Rangel, 2018).

STEM learning often involves teamwork, allowing students to collaborate with their peers. In the role of a team leader, students learn to listen, provide input, and motivate their team members. Clear and effective communication skills become essential for leaders, and STEM provides a platform to develop this aspect. When students are given responsibilities in leading or organizing STEM projects, they experience increased confidence. Leadership is not only identified as a responsibility but also an opportunity to grow and develop. By facing challenges and successfully overcoming problems, students build self-confidence that will have a positive impact on their academic and personal lives (Smith & Watson, 2020; Van Dat et al., 2023).

STEM learning encourages students to become lifelong learners. They are encouraged to remain curious, continuously seek knowledge, and adapt to the developments in science and technology. Students who lead in learning are more likely to continue their education, continually develop skills, and face challenges with a positive attitude. Through the combination of the above elements, STEM learning shapes students not only as information receivers but as active, creative, and independent learning leaders. They develop leadership in the context of research and exploration, which forms a strong foundation for success in a constantly evolving world that demands resilient leadership skills (Erdogan et al., 2022; Natarajan et al., 2021).

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The Influence of STEM Learning Models on Learning Outcomes, Mediated by 21st Century Skills and Leadership Competence, creates an educational paradigm that goes beyond conventional limitations. The STEM learning model, with its holistic approach to Science, Technology, Engineering, and Mathematics, aims not only to improve mastery of content but also to shape students into individuals ready to face the dynamics of the modern world. Through project-based STEM approaches, students are not only invited to understand scientific concepts but also to develop critical 21st-century skills such as critical thinking, creativity, collaboration, and communication (Yassir et al., 2022). This learning process provides students with direct experience in solving real-world problems, forming the main foundation for the development of 21st-century skills. Moreover, this influence also extends into the domain of leadership. The STEM learning model provides space for students to take on leadership roles in their projects. This process helps students build leadership competencies, such as decision-making, time management, and the ability to motivate and lead teams effectively.

The STEM learning model has a positive impact on student learning outcomes, 21st-century skills, and leadership competencies. The use of the STEM learning model improves students' learning outcomes in concepts such as acid-base (Kasuma et al., 2022; Munandar et al., 2020; Rahmawati et al., 2022). STEM project-based learning models integrate STEM fields and provide meaningful learning experiences, enhancing problem-solving abilities and demonstrating the benefits of mathematics in real life (Deniş Çeliker, 2020; Öztop, 2023). Computer simulations in STEM learning have a positive impact on science achievement, with simulation features and research design quality being important variables (Deniş Çeliker, 2020; N.L.P.S. Murthi et al., 2022). STEM project-based learning models improve the ability of prospective elementary school teachers to create science encyclopedias, contributing to their competency development and meeting globalization challenges (Kasuma et al., 2022; Lestari, 2019). The STEM-based scenario project design process has a positive impact on pre-service science teacher perceptions of 21st-century skills, competencies, integrated STEM teaching intentions, and attitudes towards STEM (Muttaqiin, 2023; SUWARDI, 2021). Thus, the influence of the STEM Learning Model on Learning Outcomes, Mediated by 21st Century Skills and Leadership Competence, creates a significant leap in education. Students not only become information receivers but also active actors in building their knowledge, shaping critical 21st-century skills, and honing much-needed leadership abilities in this modern era. Based on the above description, this research aims to determine the Influence of STEM Learning Models on the Learning Outcomes of Modeling and Simulation, Mediated by 21st Century Skills and Leadership Competence at ITB NOBEL Indonesia.

METHODS

This study is an ex post facto research, a type of research conducted after certain events or conditions have occurred (Tan, 2022). In this research, the researcher does not have direct control over the dependent and independent variables because these variables have already occurred or existed before the research was conducted (England, 2022). The research population includes all students at the Nobel Institute of Technology and Business, Indonesia, for the Academic Year 2022/2023. The sample consists of 60 randomly selected students from the Modeling and Simulation course. Random sampling is used in the study as

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it provides a solid basis for obtaining a representative sample from the population. By selecting sample elements randomly, each member of the population has an equal chance of being chosen, reducing the possibility of bias, enhancing internal validity, and allowing the generalization of research results to the entire population (Berndt, 2020; Cekim & Kadilar, 2020; Etikan, 2017).

The variables in this study are: (1) STEM Learning (Science, Technology, Engineering, and Mathematics), (2) 21st Century Skills, (3) Student Leadership Competence, and (4) Student Learning Outcomes in the Modeling and Simulation course. STEM learning has a tremendous impact on the development of essential skills to face the complexities of the 21st century (Kasuma et al., 2022; Muttaqiin, 2023). Students not only learn to work in teams but also share ideas and knowledge with their peers. This collaborative ability builds social, communication, and leadership skills, which are crucial in the modern interconnected work environment (Rahmawati et al., 2022; Sandi, 2021). The use of STEM learning models improves students' learning outcomes (Kasuma et al., 2022; Munandar et al., 2020; Rahmawati et al., 2022). STEM project-based learning models integrate STEM fields and provide meaningful learning experiences, enhancing problem-solving abilities, and demonstrating the benefits of mathematics in real life (Deniş Çeliker, 2020; Öztop, 2023). Computer simulations in STEM learning have a positive impact on science achievement, with simulation features and research design quality being important variables (Deniş Çeliker, 2020; N.L.P.S. Murthi et al., 2022).

The interrelation of the four variables mentioned above is illustrated in the following diagram:

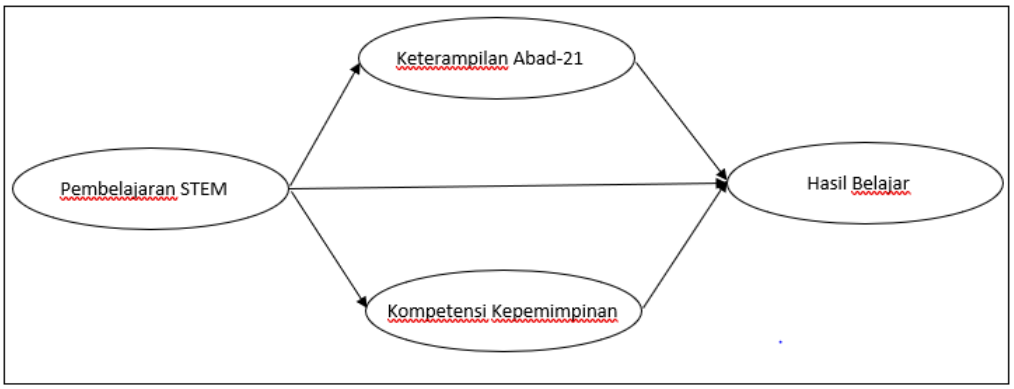

Fig. 1 Research Design

Data collection in this research used questionnaires for the variables STEM Learning, 21st Century Skills, Leadership Competence, and Learning Outcomes. The validity of the four instruments was tested using the Pearson product-moment correlation coefficient, and reliability was tested using Cronbach's Alpha. Validity ensures that the instruments measure what they are supposed to measure, while reliability ensures that the results can be replicated and relied upon. Both tests help enhance confidence in interpreting research results and ensure the accuracy of the findings obtained (Kullan et al., 2022; Sudiapermana & Setiawan, 2022).

The results of the testing using Cronbach's Alpha for the four instruments are shown in the following table:

Table 1. The results of the testing using Cronbach's Alpha for the four instruments

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No	Variable	Number of items	Cronbach Alpha Value
1	STEM Learning	20	0.812
2	21st Century Skills	28	0.833
3	Leadership Competence	22	0.861
4	Learning Outcomes	25	0.872

The next step involved analyzing the collected data using descriptive and inferential statistics (Path Analysis). The utilization of Path Analysis provides an advantage in exploring complex relationships between variables and facilitates the empirical testing of conceptual models (Fraserhealth, 2018; Harris & Gleason, 2022; Wooldredge, 2021).

FINDINGS

The summary of the results of the descriptive statistical analysis is presented in the following table:

Table 2. The summary of the results of the descriptive statistical analysis

Statistics

		STEM Learning	21st Century Skills	Leadership Competence	Learning Outcomes
N	Valid	40	40	40	40
	Missing	0	0	0	0
Mean		82.1250	103.1250	80.6000	95.2500
Median		85.0000	105.0000	92.5000	106.5000
Mode		88.00	88.00[a]	102.00	118.00
Std. Deviation		6.92520	15.12035	23.32029	23.99546
Variance		47.958	228.625	543.836	575.782
Skewness		-.380	-.021	-.574	-.409
Std. Error of Skewness		.374	.374	.374	.374
Kurtosis		-.690	-1.630	-1.216	-1.422
Std. Error of Kurtosis		.733	.733	.733	.733
Range		27.00	43.00	69.00	72.00
Minimum		70.00	83.00	38.00	50.00
Maximum		97.00	126.00	107.00	122.00
Sum		3365.00	4205.00	3224.00	3810.00

a. Multiple modes exist. The smallest value is shown

In the table above, it can be observed that all four variables have mean values smaller than their respective medians. This result indicates that more than 50% of the respondents scored above the mean score. The skewness and kurtosis values fall within the -2 to +2 interval, suggesting that the data tends to be normally distributed. Therefore, it can be said that, in general, respondents (students) have a positive perception of STEM learning models, possess 21st-century skills and high leadership competencies, and also achieve high learning outcomes in the Modeling and Simulation course.

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The percentage of respondent scores based on categories is summarized in the following table.

Table 3. The percentage of respondent scores based on categories

No	Variables	Score Category (%)			Total
		Low	Medium	High	
1	STEM Learning	20.00	50.00	30.00	100
2	21st Century Skills	17.50	42.50	40.00	100
3	Leadership Competence	12.50	45.00	42.50	100
4	Learning Outcomes	17.50	47.50	35.00	100

Next, the results of the inferential analysis (Path Analysis) are summarized in the following table:

Table 4. The results of the inferential analysis

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2.054	4.648		1.354	.184
	STEM Learning	1.787	.482	.516	3.710	.001

a. Dependent Variable: Learning_Outcomes

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.348	2.365		1.093	.181
	STEM Learning	1.527	.253	.619	6.033	.000

a. Dependent Variable: 21st Century Skills

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	6.162	36.030		1.669	.011
	STEM Learning	2.101	.427	.624	4.922	.000

a. Dependent Variable: Leadership_Competence

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.616	24.434		.066	.948
	STEM Learning	2748542.000	.306	.336	2.993	.002
	21st Century Skills	1.275	.215	.804	5.945	.000
	Leadership Competence	.280	.127	.327	2.199	.001

a. Dependent Variable: Learning_Outcomes

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Based on the table above, the following information is obtained:

1. There is a significant positive direct influence of STEM learning on learning outcomes, 21st-century skills, and leadership competencies.
2. 21st-century skills and leadership competencies also each have a significant positive direct influence on learning outcomes.
3. STEM learning has a positive and significant influence on learning outcomes mediated by 21st-century skills and leadership competencies.

DISCUSSION

The results of this study indicate a positive and significant influence of STEM (Science, Technology, Engineering, and Mathematics) learning on learning outcomes, 21st-century skills, and leadership competencies. In other words, engaging in STEM learning can make a meaningful contribution to the development of learners in several key aspects (Erdogan et al., 2022; Gok, 2021).

Firstly, the positive influence on learning outcomes affirms that STEM learning can enhance the understanding and mastery of subject matter. The interactive approach and application of scientific concepts in STEM learning have provided learners with a more comprehensive and in-depth learning experience, enabling them to achieve better academic performance. Furthermore, the finding that STEM learning has a positive influence on 21st-century skills indicates that learners engaged in this type of learning can develop skills relevant to the demands of the times, such as creativity, problem-solving, collaboration, and critical thinking. This reflects the importance of learning that not only focuses on conventional knowledge but also on the development of applicable skills in various life situations.

Lastly, the positive influence on leadership competencies indicates that STEM learning not only creates individuals who excel academically and in skills but also builds leadership character. Learners can develop the ability to lead, communicate, and collaborate with others, equipping them with the leadership skills needed in various life contexts. The finding that 21st-century skills and leadership competencies have a direct positive and significant influence on learning outcomes is interesting and relevant. This result illustrates that the development of skills and competencies, aside from academic aspects, can directly affect students' academic achievement (Kasuma et al., 2022; Setiawan et al., 2020; Zahirah & Sulistina, 2023).

Firstly, 21st-century skills, encompassing creativity, problem-solving, collaboration, and critical thinking, prove to be factors that enrich the learning process. Learners with these skills tend to be more capable of tackling learning challenges, addressing complex problems, and generating innovative solutions. Therefore, these skills not only support overall academic achievement but also help students develop an adaptive and effective learning approach.
Secondly, leadership competencies, including leadership, communication, and collaboration, also have a positive impact on learning outcomes. Leadership and collaboration skills can create a conducive learning environment, where students feel supported and motivated to achieve academic goals. Additionally, effective communication skills can facilitate better

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exchange of ideas and understanding between teachers and students, as well as among students.

The finding that STEM learning has a positive and significant influence on learning outcomes, mediated by 21st-century skills and leadership competencies, provides a deeper understanding of the complex relationship between STEM learning, skill development, and learning outcomes (Deniş Çeliker, 2020; Jannah et al., 2022; Sandi, 2021).

Firstly, through STEM learning, students can experience the contextual application of 21st-century skills. The learning process that emphasizes problem-solving, creativity, and critical thinking in the context of science and technology can stimulate the development of these skills. As a result, students engaged in STEM learning tend to have more developed 21st-century skills.

Secondly, STEM learning can also serve as a means to train and develop students' leadership competencies. Collaboration in STEM projects, responsibility for specific tasks, and the ability to work in teams can shape effective leadership. Therefore, STEM learning not only provides technical knowledge but also creates an environment where students can sharpen their leadership skills.

Moreover, these 21st-century skills and leadership competencies act as mediators between STEM learning and learning outcomes. This means that the positive influence of STEM learning on learning outcomes can be partially explained through the improvement of these skills and competencies. In other words, STEM learning provides a foundation for the development of skills and leadership, which in turn enhances academic achievement.

Thus, these findings provide a basis for a holistic approach in the development of educational curricula, showing that STEM learning not only directly benefits learning outcomes but also through the mediation of the development of skills and competencies relevant to future demands. This approach can shape graduates who are not only experts in STEM disciplines but are also ready to face the challenges of the modern world with strong skills and leadership.

CONCLUSION

The conclusions drawn from this research are as follows:

1. In general, respondents (students) have a positive perception of STEM learning, possess 21st-century skills and high leadership competencies, and achieve high learning outcomes in the Modeling and Simulation course.
2. There is a significant positive direct influence of STEM learning on learning outcomes, 21st-century skills, and leadership competencies.
3. 21st-century skills and leadership competencies also each have a significant positive direct influence on learning outcomes.
4. STEM learning has a positive and significant influence on learning outcomes mediated by 21st-century skills and leadership competencies.

Based on the above research findings, several recommendations are proposed:

1. Considering that respondents have a positive perception of STEM learning, it is suggested to continuously enhance the implementation of STEM learning in the curriculum. Ensuring active student involvement in practical activities and scientific projects can further strengthen the positive results found.

2. To improve learning outcomes, it is recommended to further develop 21st-century skills such as critical thinking, creativity, communication, and collaboration. This can be implemented through teaching methods that encourage discussions, collaborative projects, and creative activities.
3. Focus on the development of leadership competencies can also be an area of consideration. Enhancing leadership skills through the development of extracurricular programs, leadership training, or projects that require leadership skills can positively contribute to student development.
4. Conduct continuous monitoring and evaluation of STEM learning, 21st-century skills, and leadership competencies. This can help identify areas that need improvement or enhancement, allowing teaching strategies to be adjusted based on students' actual needs.
5. Encourage further research to gain a deeper understanding of the relationship between STEM learning, 21st-century skills, leadership competencies, and learning outcomes. Further research can provide additional insights and lead to the development of more effective strategies.

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