

PROBLEM-SOLVING SKILLS IN DESIGN THINKING-STEM LEARNING THROUGH NEBULA (NETWORK OF ENERGY BALANCE AND USER LIFESTYLE ACTIVITY) TO SUPPORT SUSTAINABLE DEVELOPMENT GOALS (SDGS)

ANNISA NUR KHASANAH^{1,2,*}, DADAN ROSANA¹,
INSIH WILUJENG¹, AYU GUNANINGTYAS²

¹Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

²Universitas Sebelas Maret, Surakarta, Indonesia

*Corresponding Author: annisa464fmipa.2022@student.uny.ac.id

Abstract

NEBULA is a web-based electronic learning medium designed to support personal energy-balance awareness by integrating energy intake and expenditure to promote sustainable, healthy lifestyles among university students. This study examined the effectiveness of Design Thinking-STEM (DT-STEM) learning supported by NEBULA in enhancing students' problem-solving skills. A quasi-experimental pretest-posttest control group design was implemented by comparing an experimental group receiving DT-STEM with NEBULA and a control group receiving conventional STEM learning. Problem-solving skills were assessed using essay-based instruments aligned with established problem-solving indicators. The findings indicate that students in the experimental group demonstrated higher problem-solving performance across multiple aspects, particularly in visualizing problems, describing problems in scientific terms, and executing solution plans. These results suggest that technology-assisted DT-STEM learning through NEBULA effectively fosters problem-solving competence and 21st-century skills, while simultaneously supporting Sustainable Development Goals (SDGs).

Keywords: Design thinking, NEBULA, Problem solving, SDGs, STEM.

1. Introduction

The 21st century is characterized by the increasing interconnectedness of science and technology, requiring education systems to equip learners with competencies to face global challenges [1-6]. Education plays a central role in improving human quality of life by fostering knowledge and skills that support adaptation to complex societal demands [7]. An important educational outcome aligned with national goals is the development of healthy individuals, as health literacy is essential for maintaining optimal bodily function in daily activities. However, students' health literacy remains relatively low, with many learners experiencing difficulties in applying health-related information, potentially affecting the quality of human resources in a competitive knowledge-based society [8].

The urgency of addressing health-related issues through problem-solving is further intensified by limited nutritional awareness and rising obesity rates in Indonesia. Nutritional concepts are often abstract for students, necessitating instructional strategies that connect scientific knowledge with everyday consumption patterns, including traditional culinary contexts [9]. Contemporary educational paradigms emphasize active learning, where students are encouraged to seek information, formulate health-related problems, and collaboratively develop solutions to real-world challenges. Consequently, problem-solving skills are essential for systematically identifying, analysing, and resolving health-related problems [10, 11].

Despite their importance, students' problem-solving skills in science and health education remain weak, as reflected in international assessments such as PISA. Learners often struggle to understand problems, plan strategies, and evaluate solutions, a condition exacerbated by instructional practices that prioritize rote learning over reflective and analytical thinking [12-14]. This highlights the need for innovative instructional approaches that actively engage students in constructing and applying knowledge.

Design thinking (DT) offers a user-centred and iterative framework for addressing complex health and nutritional problems [15]. When integrated with STEM education, DT enables learners to solve authentic problems by combining scientific understanding with technological and engineering processes [16-19]. STEM-based learning has been shown to enhance problem-solving abilities through engagement with real-life health issues [9, 20].

In response to these challenges, this study investigates DT-STEM (DT-STEM) learning supported by the electronic learning medium NEBULA (network of energy balance and user lifestyle activity). NEBULA integrates real-time digital tools to facilitate data-driven understanding of personal energy balance, positioning technology as a cognitive and decision-making system rather than a supplementary aid. This study extends technology-enhanced STEM pedagogy by embedding health literacy within DT-STEM problem-solving processes and contributes an innovative instructional model that supports sustainable development goals (SDGs), particularly SDG 3 (good health and well-being) and SDG 4 (quality education).

2. Literature Review

2.1. Design thinking

DT is a human-centred innovation approach that emphasizes empathy, creativity, and iterative problem solving to generate effective solutions to complex problems.

In educational contexts, DT facilitates learners' engagement with authentic problems by encouraging experimentation, reflection, and learning from failure, thereby strengthening creativity and problem-solving competence [21].

DT has been widely applied across disciplines, including education, business, and healthcare, due to its ability to reduce cognitive bias and promote innovative thinking through structured yet flexible stages [22]. Design Thinking has five phases namely empathize, define, ideate, prototype, and test. Empathize is understand and observe problems by paying attention to the characteristics and needs of product users by involving empathetic methods. Define is defining problems according to user needs with the principle of empathy to formulate goals. Define is create as many solution ideas as possible and select potential ideas to be designed according to user needs. Ideate is developing prototypes of activities, systems, or products to test and validate ideas appropriately according to user needs. Test is testing the effectiveness of the prototype by evaluating the strengths and weaknesses of the product from user feedback which is useful for developing and refining the design.

2.2. STEM education

STEM education integrates science, technology, engineering, and mathematics to foster interdisciplinary learning and real-world problem-solving skills [23]. As an instructional approach, STEM emphasizes inquiry, collaboration, and the application of scientific knowledge through technological and engineering processes, enabling learners to connect theory with practice [24].

Integrated STEM learning has been shown to enhance students' abilities to identify, analyse, and evaluate complex problems by linking multiple disciplinary perspectives without rigid separation [25, 26]. Empirical studies indicate that STEM-based learning environments promote meaningful engagement and improve problem-solving performance when students are involved in authentic, context-based tasks [27, 28].

2.3. Problem solving and electronic learning media

Problem-solving skills are essential cognitive competencies involving the processes of understanding problems, generating strategies, executing solutions, and evaluating outcomes [29, 30]. In science education, effective problem solving requires learners to translate abstract concepts into scientific representations and actionable solutions [31].

Electronic learning media play a critical role in supporting this process by providing interactive and data-driven environments that function as cognitive scaffolding [32]. Digital platforms enable learners to visualize variables, manipulate data, and engage with real-world information, thereby reducing cognitive load and strengthening higher-order thinking skills [33]. The application of electronic learning media within DT-STEM learning, as illustrated in Figs. 1-5, demonstrates how technology can transform abstract nutritional concepts into measurable and analysable data, supporting systematic problem solving in health-related contexts.

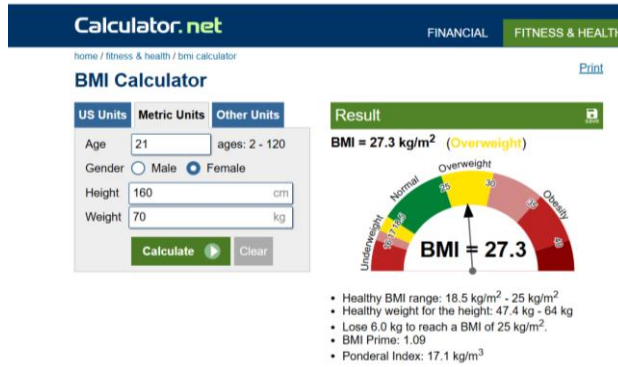


Fig. 1. BMI calculation using calculator.net.



Fig. 2. BMR and TDEE calculation using calculator.net.



Fig. 3. Caloric intake information using the fatsecret web platform.

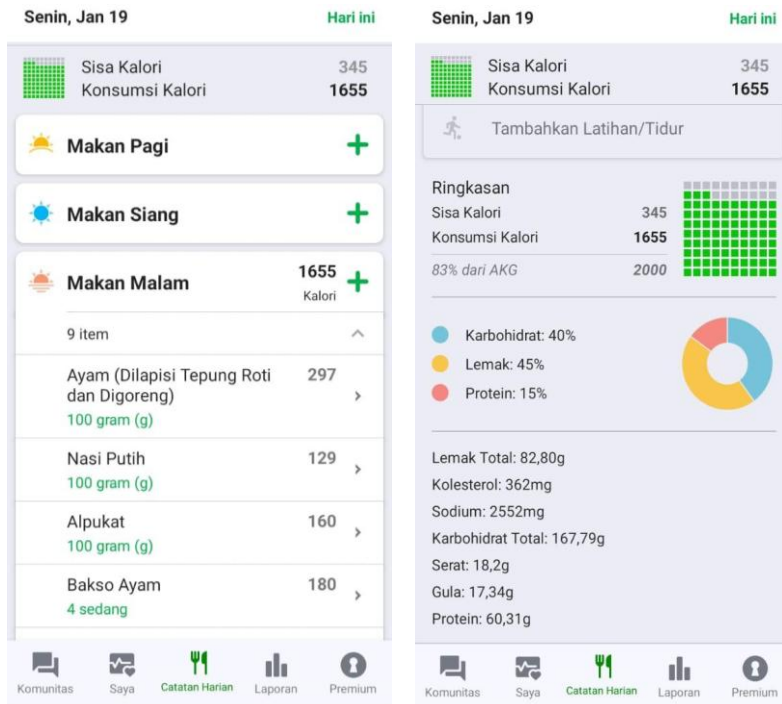


Fig. 4. FatSecret mobile application interface.

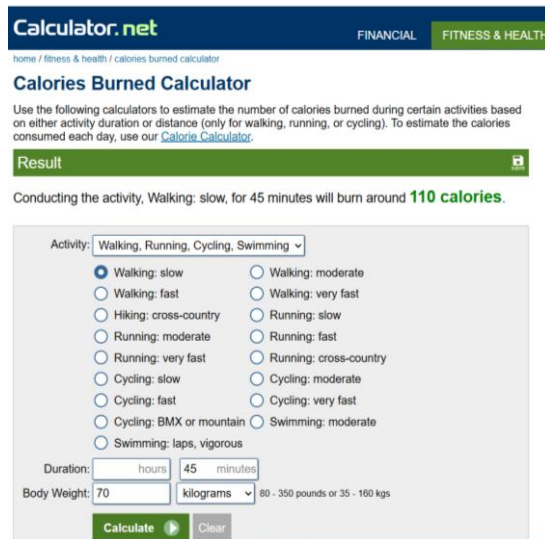


Fig. 5. Energy expenditure estimation from physical activities.

3. Methodology

This study employed a quasi-experimental pretest-posttest control group design to examine the effect of design thinking-STEM (DT-STEM) learning supported by the NEBULA electronic learning medium on students' problem-solving skills. The

participants were fifth-semester university students from a public university in Surakarta, Indonesia during the 2024/2025 academic year, selected using cluster random sampling. The experimental group received DT-STEM instruction integrated with NEBULA, while the control group received conventional STEM learning. Problem-solving skills were assessed using essay-based tests developed from the indicators proposed [29]. Data were analysed using statistical software, including assumption testing and comparative analysis to determine the effectiveness of the intervention.

4. Results and Discussion

Before hypothesis testing, prerequisite analyses were conducted to ensure that the data met parametric assumptions. The normality of N-Gain scores for both groups was examined using the Kolmogorov-Smirnov and Shapiro-Wilk tests, as presented in Table 1. The results indicate that the experimental and control groups were normally distributed, with significance values exceeding the 0.05 threshold. In addition, the homogeneity of variance was tested using Levene's Test. As shown in Table 2, the significance value based on the mean exceeded 0.05, confirming that the variances between groups were homogeneous. These findings justify the use of parametric statistical analysis.

Table 1. Tests of normality of N-Gain scores.

Group	Test	Statistic	df	Sig.
Experimental	Kolmogorov-Smirnov	0.130	26	0.200*
	Shapiro-Wilk	0.949	26	0.216
Control	Kolmogorov-Smirnov	0.093	25	0.200*
	Shapiro-Wilk	0.981	25	0.898

Table 2. Test of homogeneity of variances (Levene's test).

Method	Levene Statistic	df1	df2	Sig.
Based on Mean	3.383	1	49	0.072
Based on Median	2.911	1	49	0.094
Based on Median (adjusted df)	2.911	1	43.980	0.095
Based on the Trimmed Mean	3.369	1	49	0.072

Following the fulfilment of these assumptions, a One-Way ANOVA was conducted to compare the N-Gain scores of problem-solving skills between the experimental and control groups. The ANOVA results, summarized in Table 3, revealed a statistically significant difference between groups ($p < 0.001$). This result indicates that design thinking-STEM (DT-STEM) learning supported by the NEBULA electronic learning medium had a significant effect on students' problem-solving skills compared to conventional STEM learning [34-36].

Table 3. One-way ANOVA results for N-Gain scores.

Source	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	0.131	1	0.131	14.913	< .001
Within Groups	0.430	49	0.009		
Total	0.561	50			

To determine the magnitude of the intervention effect, effect size analysis was performed. As presented in Table 4, the eta-squared value indicates a moderate practical impact of the DT-STEM learning intervention. This suggests that the observed improvement in problem-solving skills was not only statistically significant but also meaningful in an educational context. The integration of DT-STEM with digital learning tools enabled students to engage more deeply with authentic health-related problems, reinforcing systematic reasoning and solution-oriented thinking.

Table 4. ANOVA Effect Size Estimates

Effect Size Measure	Point Estimate	95% CI Lower	95% CI Upper
Eta-squared	0.233	0.056	0.410
Epsilon-squared	0.218	0.037	0.398
Omega-squared (Fixed)	0.214	0.036	0.393
Omega-squared (Random)	0.214	0.036	0.393

A more detailed comparison of students’ problem-solving performance across specific aspects is illustrated in Fig. 6. The experimental group demonstrated greater improvements across all indicators, particularly in visualizing the problem, describing the problem in scientific terms, planning solutions, and executing solution strategies. These gains align closely with the Design Thinking phases, where empathy and problem definition serve as critical foundations for effective problem solving. Although the control group showed relatively higher performance in the “plan a solution” and “check and evaluate” aspect, the experimental group exhibited more consistent improvement from pretest to posttest across all dimensions.

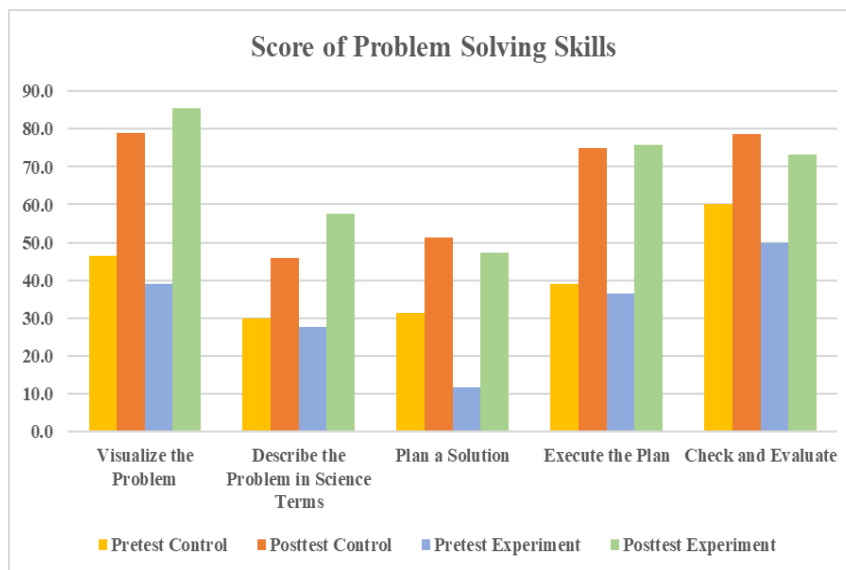


Fig. 6. Comparison of problem-solving skills scores.

The use of NEBULA, supported by digital tools such as Calculator.net and FatSecret, functioned as cognitive scaffolding that transformed abstract nutritional concepts into measurable and analysable data. This technology-assisted learning environment reduced cognitive load and facilitated higher-order thinking, enabling students to focus on analysis, decision making, and solution execution. Overall, these findings demonstrate that DT-STEM learning supported by NEBULA effectively enhances problem-solving skills. NEBULA was developed in the form of a meal plan equipped with daily activity calorie calculations to examine energy balance in more detail, as illustrated in Fig. 7, while contributing to SDGs, particularly SDG 3 (good health and well-being) and SDG 4 (quality education) [37].

Waktu Makan	Menu	Jumlah Kalori (Kkal)	Kandungan Gizi		
			Karbohidrat (g)	Protein (g)	Lemak (g)
Pagi	Nasi Putih	129	27,9	2,66	0,28
	Telur Dadar	93	0,42	6,48	7,33
	Tempe Goreng (2 Potong)	68	3,58	3,99	4,56
	Teh Manis	55	14,36	0	0
	Air Putih	0	0	0	0
Total :		345	46,26	13,13	12,17
Snack Pagi	Jeruk	62	15,39	1,23	0,16
	Roti Tawar	100	18,5	3,5	1,5
Total :		162	33,89	4,73	1,66
Siang	Nasi Putih	129	27,9	2,66	0,28
	Ayam Goreng	260	10,76	21,93	14,55
	Sayur Bayam	36	7,64	1,79	0,37
	Tahu Goreng (1 Potong)	35	1,36	2,23	2,62
Total :		460	47,66	28,61	17,82
Snack Sore	Pisang Coklat	90	16	2	2
Total :		on	16	?	?

Fig. 7. Example Mealplan NEBULA.

5. Conclusions

This study demonstrates that design thinking-STEM (DT-STEM) learning supported by the NEBULA electronic learning medium is effective in enhancing students’ problem-solving skills. The integration of human-centred design processes with STEM learning and data-driven digital tools enables students to better visualize problems, construct scientific representations, and execute solution strategies in health-related contexts. Statistical analysis confirms that the observed improvement is both significant and educationally meaningful. By transforming abstract nutritional concepts into measurable data, NEBULA functions as a cognitive and decision-support system that promotes higher-order thinking. Overall, this instructional model contributes to innovative technology-enhanced STEM education while supporting SDGs, particularly SDG 3 (good health and well-being) and SDG 4 (quality education).

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