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Development of Argumentation Tools Based on the Engineering Design Process to Improve Students' Argumentation Skills

Abstract

Argumentation skills play a vital role in students' ability to master the learning process because, by employing these skills, they can explain real-world phenomena scientifically. This research focused on developing an argumentation tool based on the engineering design process (EDP) to improve students' argumentation skills in science classrooms. This study utilised the research methods outlined by Plomp & Nieveen, which include problem identification, design, and implementation stages. This study, which involved 150 junior high school student participants, was conducted to implement the argumentation tool as a learning material to help students to understand heat transfer information in science learning. The indicators of argumentation skills included claims, evidence, and reasoning. The study results showed that five experts validated the argumentation tool in science learning development as appropriate for implementation as a practical tool in the science learning classroom. Furthermore, *students' argumentation skills improved significantly, mainly related to developing claims and collecting evidence based on the N-gain evaluation.*

Keywords: *argumentation tool, engineering design process, argumentation tool*

Introduction

Argumentation skills are critical skills to be mastered by today's students. Through these skills, students build their agreement between knowledge and scientific explanation. The Next Generation Science Standards (NGSS) place argumentation among the scientific and engineering practices relevant to science and other subjects with respect to daily life problems (NGSS, 2013). Argumentation is a central skill because it enables students to demonstrate their ability to explain scientific phenomena systematically so that the explanation is easy to understand (Osborne et al., 2004). The skills of reasoning and argumentation based on evidence are critical to identifying the best explanation for natural phenomena.

However, evidence has shown that students' argumentation skill level for explaining science phenomena remains low (Dawson & Carson, 2020). Despite students' argumentation skills being included in the evaluation of their mastery of science by the Program for International Student Assessment (PISSA), only seven countries have significantly improved the quality of science, mathematics, and reading skills (OECD, 2019). This problem has emerged because teachers have faced challenges in giving students opportunities to engage in solving real-world problems with argumentation (Guilfoyle et al., 2021). Moreover, teachers have been unable to provide students access to facilities where they can interact to improve their argumentation skills (Rizkika et al., 2022). Teachers should provide an alternative learning approach to increase students' opportunities to engage in argumentation (Rapanta, 2021).

One alternative approach teachers can utilise when they engage students in practising their debate skills in the classroom is using the argumentation tool. This tool was developed through the website system to give students experiences that can improve their argumentation skills. The online system is an effective instrument for presenting argumentation instruction and activities for students familiar with social networking, mainly in the post-covid era (Putra et al., 2021; Tsai, 2015). Furthermore, using the argumentation tool online can help educators control students' scientific activities in the classroom (Noroozi & Hatami, 2019). A challenge to developing students' argumentation skills in the classroom using the process integrated with the website system is that the educator developer must select the proper instructional strategies. The use of the engineering design process (EDP) is one strategy that involves students in experiences with solving real-world problems and gives them an opportunity to systematically explain a science phenomenon (Putra et al., 2021). Research on the EDP has been integrated into the learning activity to show students' learning progression (Putra & Kumano, 2018).

Using the EDP, students can follow the sequence of steps that begins with defining a problem and ends with developing a solution to improve their argumentation skills. This study focused on developing the argumentation tool based on the EDP steps to improve students' argumentation skills. It was necessary that the argumentation tools based on EDP were tested to be valid by experts' validation, and it also should improve students' argumentation skills.

Research Methodology

General Background of Research

This research employed the methods adopted by Plomp and Nieveen (2013). The steps involved in applying the argumentation tool were problem identification, design and implementation, and evaluation. Problem identification focused on the need for an argumentation tool for students in a specific area. The design and implementation steps involved the authors' development of the argumentation tool for improving students' argumentation skills in junior high school.

Research Sample

Purposive sampling was used in this research to select student participants who lived in the coffee farming area. The sample selected included 150 junior high school students from two junior high schools in one district near a coffee farming area in the East Java Province of Indonesia. The demographics of the sample population for this study are presented in Table 1.

Table 1. Demographics of students from two junior high schools

Student demographic	*N*	Percentage
Male	67	45%
Female	83	55%
Grade	7th	100%
Average age	13.6	100%

Instrument and Procedures

Instruments in this research comprised an expert validation survey, a student observation protocol, and an argumentation pre- and post-test (Cheung & Slavin, 2013). The experts used the validation survey to grade the argumentation tool's quality by evaluating three components: construct, the content of the science material, and the appearance of the argumentation tool. The student observation protocol was designed for students to use with the argumentation tool in the classroom. The argumentation pre- and post-tests consisted of 12 items grouped according to the argumentation indicators developed by Sampson (2020): claims, evidence, and reasoning.

After the authors developed the argumentation tool, five graders conducted the expert validation, scoring the three components of the tool from 1 (poor) to 5 (good). After the experts validated the argumentation tool, the next step was the implementation of the tool in the classroom. Students were observed while they employed the argumentation tool in the classroom, and the teachers were recorded as they implemented the tool. The recording of the teacher implementation of the argumentation tool was shared with 40 observers, who assigned the students using argumentation tool grades ranging from 1 (poor) to 4 (good) based on the observation protocol. In the last part of this step, students were asked to complete the argumentation test based on the argumentation tool. The results of the post-test were compared with the pre-test results, and the rate of improvement was calculated using *N-gain.*

Data Analysis

The results from the expert validation surveys and the student protocol observations were calculated to determine the total average for each item, which was then converted into a percentage. Table 2 shows the categories and descriptions of the results obtained for the validation and student observation protocol. The internal consistency of the grader results related to the student protocol was also analysed based on *Cronbach's alpha.*

Table 2. Analysis of validation and observation protocol results

Criteria	Grade	Category	Description
Expert Validation	25–55%	Not acceptable	Product cannot be used
	56–70%	Not Quite valid	Product needs major revision
	71–85%	Valid	Product needs minor revision
	86–100%	Strongly valid	Product can be used in learning

Criteria	Grade	Category	Description
Student Observation Protocol	25–50%	Not good	Implementation failed
	51–79%	Moderate	Implementation needs to be adjusted
	80–100%	Good	Implementation went well

The effectiveness of the argumentation tool for improving students' argumentation skills was analysed based on the pre-test and post-test scores. The *Normalize-gain*, or *N-gain,* value was calculated, which is a measure of change in average class score between pre-test and post-test. The N-gain value can be categorised as follows: low ($N\text{-}gain < 0.3$,), moderate ($0.3 \leq N\text{-}gain < 0.7$), and high ($N\text{-}gain \geq 0.7$).

Results

The development of argumentation tool was developed using a Google website. The appearance of the argumentation tool is represented in Figure 1. The argumentation tool based on EDP gives students access to improve their argumentation skills through several features, such as the home page, attendance list, science material, student's worksheet, argumentation evaluation, and profile.

The home page provided general information about the argumentation tool, the purpose of the tool and the reason for developing it, and a general guided interaction experience with the tool. The attendance list was utilised to track which students attended the class and used the argumentation tool. Science material was the science subject content about coffee processing. The student worksheet included the EDP problem that students were given to solve based on a situation in the context of coffee processing. The EDP in this student's worksheet followed

Figure 1. Screenshot of argumentation tool developed by Google site

the EDP steps. Argument evaluation is the test that aims to measure the students' argumentation skills after using this tool. The profile described the developer of this argumentation tool.

Five experts conducted the validation in the field of learning media development who had science education backgrounds, which enabled them to understand the science content. The results of the experts' validation are shown in Table 3.

Table 3. Results of the validation of the argumentation tool based on ratings of five experts

Criterion	Expert Validator No. (grade in percentage)					Average score of each criterion	Category
	1	2	3	4	5		
Content of science material	85	85	90	100	85	89	Strongly Valid
Argumentation tool's interface	89	85	85	95	89	89	Strongly Valid
Legibility	98	85	85	85	85	88	Strongly Valid
Graphics	85	81	81	85	85	84	Valid
Total Average Score						**88**	**Strongly Valid**

Based on the data presented in Table 3, the content of the science learning materials, which was measured based on the stability of the science concept concerning explaining heat transfer through coffee processing, were deemed valid. Five experts evaluated the argumentation tool, and based on the results, the average score assigned to the tool was 88. This score indicates that the argumentation tool was valid, and can be implemented in the classroom.

After the argumentation tool was validated, teachers used the argumentation tool to teach a lesson on heat transfer. Teachers implemented the argumentation tool to guide students in searching for information, conduct experiments using the student worksheet, and test the students' argumentation skills. The results of the teachers' implementation of the tool in the science classroom are described in Table 4. Forty observers graded the quality of teaching skills using the argumentation tool.

Based on the scores as presented in Table 4, the student observation protocol in the science classroom was evaluated overall, on average, as good and reliable. Students used the argumentation tool to search for science subject material about the heat transfer process. Furthermore, students discovered a relationship

Table 4. Results of implementation of argumentation tool in a science classroom

No.	Items of observation	Average score (%)	Criteria	Cronbach's alpha
1	Students pay attention to the science material in argumentation tool.	80%	Well	0.85 (consistent)
2	Students actively ask teacher questions about the material when they have difficulty with the argumentation tool.	83%	Well	
3	Students observe and perform experiments using the argumentation tool in collaboration.	84%	Well	
4	Students note the results of their observations and experiments based on the argumentation tool.	90%	Well	
5	Students present the results of the experiment based on the argumentation tool.	63%	Adjusted	

between coffee processing and heat transfer knowledge. The students used their understanding of the subject matter to conduct experiments following the EDP steps based on the argumentation tool provided. The results of the effectiveness are presented in Table 5.

Table 5. Pre-test and post-test results of students' argumentation skills

Indicator	N		Pre-test				Post-test				*N-gain*
	Female	*Male*	*Min*	*Max*	*Mean*	*SD*	*Min*	*Max*	*Mean*	*SD*	
Claim	83	67	0	92	45	29	50	100	82	15	0.6
Evidence	83	67	0	85	42	24	57	100	87	11	0.7
Reasoning	83	67	10	82	44	25	18	100	70	22	0.5

As indicated in Table 5, the *N-gain* for the students' performance in the claim and reasoning components of the argumentation tool fell in the moderate category, but the students' skills in collecting evidence related to the problem given in the argumentation tool were high. Moreover, the *N-gain* calculations showed that students' argumentation skills overall improved after using this tool.

Discussion

Based on the experts' validation, the argumentation tool was suitable for further development to improve students' argumentation skills using the EDP steps. The engineering design can help students better understand science concepts they have learned in the science classroom and draw a connection between those concepts and real-world problems (Guzey et al., 2019). Furthermore, by following the EDP, students think in terms of sequences when presented with the task of defining the problem, learning about the situation, determining the related scientific concept, designing potential solutions, and deciding which is best based on the data they collected. This argumentation tool gave students a task that started with a problem letter and culminated with the students' decision on the processing of coffee. Students collected data from the problem letter related to the problem as an EDP task. They then evaluated the evidence needed to support their claim about coffee processing. Moreover, the design interface in the argumentation tool gave the students the opportunity to use the menu on the website to easily access learning materials because the argumentation tool was developed using the online system. The integration of science materials on the website was effective in providing explanations of science concepts. Students could manage the process of accessing material based on their evidence needs. Science learning materials were integrated into this argumentation tool because the EDP step was necessary for students to learn the science concept to solve the problem given in the science classroom.

The argumentation tool provided students with a sequential menu that enabled them to apply the tool using basic skills through to the point of using their more advanced skills. For example, the first time using this tool, students can learn science subject matter before they are challenged to solve a real-world problem based on the student worksheet. Valid learning material must be able to give students the opportunity to learn class content ranging from simple to complex concepts. The argumentation tool design also could be accessed online so that students could experience being independent learners based on their skill level to follow the argumentation toll sequence (Mamun et al., 2020). Additionally, based on the experts' validation results, this argumentation tool was reliable for use to improve students' understanding of the science concepts. The learning materials were also validated based on readability and the accompanying graphics that support the science concept (Rizkika et al., 2022).

The practical component of this argumentation tool was implemented in two schools. The results indicated that the argumentation tool was appropriate to implement as a learning material in the science classroom. This tool facilitated

students' ability to pay attention to real-world problems and improve their critical thinking skills for problem-solving. Although the argumentation tool was developed using an online system, teachers in the classroom played an active role in its implementation by giving directions to students on how to use the tool for science learning. In these classes, the students demonstrated active learning by discussing and collaborating to solve the problem given by the teacher. In collaboration with their peers, students explored alternative solutions and presented reasonable arguments to strengthen their ideas (Noroozi & Hatami, 2019). Students developed their reasoning for the coffee processing together to get the best results based on several items of evidence they had gathered to support the claim (Sampson et al., 2020; Songsil et al., 2019). Further, the students used this tool for the pre-test to build their understanding of heat transfer in the science materials provided.

The *N-gain* value showed that this argumentation tool improved the students' argumentation skills. As indicated in Table 5, students' claims and collecting evidence for the link between coffee processing and the concept of heat transfer obtained high scores. Students stated their claims about alternative solutions when they read the problem letter accessed through the argumentation tool. The statement of the student's claim was supported by evidence as needed and the constraints listed in the problem letter. Through the argumentation tool, students can practice building their argumentation skills, particularly their ability to make claims, collect evidence, and develop sound reasoning. However, the argumentation tool was validated as appropriate to implement in the classroom. This tool showed evidence that in the science learning process, students not only learned about the science concept. However, students were emphasised more to give solutions based on the real-world situation. The EDP steps could be integrated into the argumentation tool so that the teacher might follow those steps easily.

Conclusion

The purpose of this research was to measure the validity of an argumentation tool, to implement the tool in the science classroom, and to improve students' argumentation skills by using this tool. The results indicated that five experts validated the argumentation tool in science concepts and learning media development. Furthermore, when the argumentation tool was implemented in the classroom, the students actively learned science concepts based on the use of the argumentation tool. The argumentation tool effectively improved students' argumentation skills, with students' performance in the claim and evidence categories ranked high,

whereas their reasoning skills were evaluated as moderate. The EDP step played an important role in this research. Through EDP, students learn about science concepts and improve their skills to develop to design solutions. Students also collected evidence based on the argumentation tools to support their claims using reasoning skills.

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