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Fostering argumentation skills through STEM-EDP project: An exploration of students' argumentation pattern

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Abstract: This study aims to explore students' ability to form argumentation patterns based on aspects of Toulmin's Argument Pattern (TAP) in Science, Technology, Engineering and Mathematics (STEM)-based learning. Data collection was carried out through STEM-based worksheet which has 12 argumentation items that are in accordance with the Engineering Design Process (EDP) stages. The data was then analyzed qualitatively. This research was conducted at one of the junior high schools in Samarinda, Indonesia in the even semester of the 2022/2023 academic year. The population in this study were all students of grade VII totaling 9 classes with a sample of grade VII-F consisting of 32 students. The results showed that the students' argumentation patterns consisted of several patterns, namely, Claim & Data (C-D); Claims, Data, & Warrants (C-D-W); Claims, Data, Warrants, & Backing (C-D-W-B); Claim, Data, Warrant, Backing, and Rebuttal (C-D-W-B-R) with the C-D pattern is the most common argumentation pattern. Students still need to be facilitated with learning that can guide students in forming more complex arguments so that an argumentation pattern is formed that includes warrant, backing, and rebuttal aspects.

Keywords: *STEM learning, argumentation skill, Toulmin's argument pattern, climate change*

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INTRODUCTION

The development of education in the 21st century requires students to master various skills that can be realized through learning in the classroom (Hidayatullah *et al.*, 2021). One of the skills that needs to be developed is the ability to argue (Noviyanti *et al.*, 2019; Redhana, 2019). Argumentation in science learning is very different from the understanding of argumentation in general which has the meaning of exchanging opinions and emotions between two rivals who aim to defeat each other (Faize *et al.*, 2018). The ability to argue in science learning is the ability to re-communicate the material that has been taught with accompanying evidence so that a conclusion can be drawn (Hasanah *et al.*, 2022).

Argumentation has an important role in science education because it involves students in analyzing problems regarding specific topics (Hasnunidah *et al.*, 2022). Through argumentation, learning not only develops understanding of concepts but also to learn to convey back concepts that students have understood (Syerliana *et al.*, 2018). However, argumentation skills are still often ignored in classroom learning (Bravo-Torija & Jiménez-

Aleixandre, 2017). Based on research conducted by Zairina and Hidayati (2022) it is known that students' argumentation abilities fall into the less category. Students' argumentation skills are still dominated by basic level argumentation. Students are still not able to make high-level arguments (Utomo *et al.*, 2019). One of the factors is the weak ability of students' argumentation because teachers still do not use strategies, approaches, and innovative learning models in the learning process in class (Suartha *et al.*, 2020). Efforts that can be made to optimize learning are to apply a practical and innovative approach to facilitate the learning process in the classroom. One approach that can be used is the STEM (Science, Technology, Engineering, and Mathematics) approach (Wahyuni, 2021).

STEM-based learning is an approach that integrates more than one discipline, namely science, technology, engineering and mathematics (Octaviyani *et al.*, 2020). STEM can be defined as an approach that combines theory and practice by combining the four disciplines as well as direct experience in the real life (Bozkurt *et al.*, 2019). Characteristic of the STEM approach is connecting the theory taught with surrounding problems so that it will provide real experiences for students (Santoso & Arif, 2021). STEM acts as a means for students to create ideas based on science and technology through thinking and exploring activities in solving problems based on four integrated scientific disciplines so that they can produce a very appropriate solution (Indarwati *et al.*, 2021). STEM knowledge can be used to collaborate with other people, develop skills, and find solutions to problems so that it is very useful for supporting future career life (Krajcik & Delen, 2017). STEM learning is able to facilitate students in forming arguments. For example, in research conducted by Roja *et al.* (2020) it was discovered that students' verbal and written argumentation abilities were in the good category after implementing STEM learning. In addition, the application of STEM through project activities can increase students' understanding of concepts which can help students build quality arguments (Paramita *et al.*, 2020). STEM has one characteristic that must appear in the learning process, namely the Engineering Design Process (EDP) (Ulum *et al.*, 2021).

EDP is a model that focuses on techniques to help students analyze real life problems through the knowledge they have acquired and provide solutions to problems in the form of products (Wind *et al.*s, 2019). EDP consists of several stages which include define, learn, plan, try, test and decide (Putra, *et al.*, 2021; Sulaeman *et al.*, 2021). EDP places greater emphasis on the design or engineering process for students to solve and find solutions to real life problems (Widianawatia & Sulisworo, 2020; Suroto, 2021). EDP in the learning process can create new activities that teach students engineering design to improve STEM abilities (Widiyanti *et al.*, 2021). Activities at each stage of the EDP allow students to collect data that can be used to support their arguments (Putra, Ahmad *et al.*, 2023). Apart from that, EDP is able to facilitate the development of students' arguments through collaborative activities in small group discussions (Putra, Sulaeman *et al.*, 2023).

Previous research conducted by Gülen and Yaman (2019) shows that integrating STEM learning with the Toulmin model can improve students' performance in forming arguments in class. Toulmin's Argument Pattern (TAP) model is a technique for analyzing and grouping arguments (Widhi et al, 2021). TAP is the most complete argumentation pattern consisting of claim, data, warrant, backing, qualifier and rebuttal (Suartha *et al.*, 2020;

Castro *et al.*, 2021; Fakhriyah *et al.*, 2022). Basically, argumentation focuses on claims that are opinions or ideas; data are facts used as evidence to support claims; warrants are reasons that link data and claims; backing are assumptions that support the warrant; and rebuttal indicate the exclusion of untrue and invalid claims. (Aviyanti, 2020; Admoko *et al.*, 2021). The Toulmin Argumentation Model has been the basis for several previous researchers on argumentation (Lobczowski *et al.*, 2020).

Based on the problems previously described STEM-based learning with the EDP model can be used to improve student performance in forming arguments. The TAP model can be used as a tool to analyze students' argumentation abilities. Therefore, this research was conducted to explore student argumentation patterns based on the TAP model based on STEM-EDP learning. The STEM-EDP approach is expected to make it easier for students to build their arguments through project activities.

METHOD

This research uses a qualitative approach. The population in this study were all grade VII students at SMP Negeri 21 Samarinda for the 2022/2023 academic year. The sample used in this study was students of grade VII F, totaling 32 students. The sampling technique in this study was carried out by using a random sampling technique. Data collection techniques were carried out using STEM-EDP based worksheet.

This research consisted of 4 meetings with material about substances and their changes. The first meeting of students focuses on substances and its changes. In the second, third and fourth meetings, students worked on STEM-EDP based worksheets on the topic of climate change. Table 1 shows the meeting, EDP stages and TAP aspects.

Table 1
The stages of EDP and TAP aspect

Meeting	EDP Syntaxs	TAP Aspect
1	Learn	Data
2	Define and learn	Claim and data
3	Plan and try	Claim, data, warrant
4	Test and decide	Claim, data, warrant, backing and rebuttal

STEM-EDP encourages students to use engineering aspects in solving problems, namely regarding the topic of climate change. The worksheet consists of several EDP stages and essay questions where students have to answer 12 questions argumentatively which will then be analyzed using TAP. To be able to find out the pattern of student argumentation, it is necessary to know the indicators of the appearance of the TAP aspect. Table 2 is an indicator of the emergence of each aspect of TAP (Maulyda, *et al.*, 2021).

FINDINGS AND DISCUSSION

After the 4 meetings of STEM EDP Project, students actively participate in groups. Each stage of EDP is able to facilitate students in forming arguments which will then be analyzed using TAP. During the process of students taking part in the project, argumentation is measured through worksheets. Students work on worksheets in groups. Through EDP activities, students discuss in groups to form their arguments. Through discussion activities,

students can collaborate in forming good arguments. In EDP activities at the define stage, students are directed to form a claim; at the learn, plan, and try stages, students are directed to form claims and data; at the test stage, students are directed to form claims, data, and warrants; and at the decide stage, students are directed to form a claim, data, warrant, backing, and rebuttal. Through each stage of EDP, students' argumentation patterns can be seen through a combination of each aspect of TAP.

Table 2
Toulmin's Argument Element

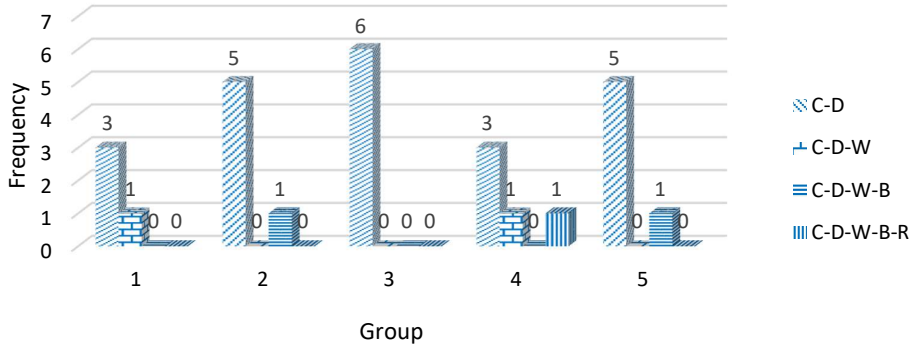
TAP Aspect	Description	Identification Question
Claim (C)	Position Statement is a statement that contains a person's opinion or position on an issue	- What is actually being claimed? - What is supported? - Where do you stand on this issue or topic?
Data (D)	Arguments can take the form of experimental observations, general knowledge, statistical data, and someone's testimony	- What is the basis of the argument?
Warrant (W)	The bridge that connects the position statement with data or facts	- What basis is used to reason relevant and factual?
Backing (B)	Supporting data or statements to strengthen an argument	- What can support and strengthen the proposed guarantee?
Rebuttal (R)	Conditions that allow rejection or refutation of the arguments given	- What factors can invalidate this argument?

The pattern of student argumentation was seen from the results of the worksheets given to the sample class, namely grade VII-F, which consisted of 5 groups where each group consisted of 6-7 students. The argumentation pattern of each group was obtained after being given treatment in the form of STEM-based learning. This research was conducted over 4 meetings. At the first meeting, students are given an understanding material about substances and its changes. Then it continues with the second, third and fourth meetings where students start working on the worksheets. During three meetings, students worked on a worksheet in which the EDP stages were divided for each meeting. The worksheet is divided into 3 meetings. At the first meeting, students were given material regarding the states of matter and their changes. At the second meeting, students were given material about climate change and then students started working on worksheets at the define and learn stage. At the third meeting, students worked on worksheets at the plan and try stages. Then, at the fourth meeting, students work on worksheets at the test and decide. After holding 4 meetings, students' answers were obtained. The researchers then processed these results to obtain students' argumentation patterns.

Students' argumentation patterns are obtained by looking at the relationship between TAP aspects which consist of Claim, Data, Warrant, Backing and Rebuttal aspects. The results obtained from the worksheets are that there are 27 student group answers that form an argumentation pattern on the worksheets, the patterns formed include Claim-Data (C-D), Claim-Data-Warrant (C-D-W), Claim-Data-Warrant-Backing (C-D-W-B), and Claim-Data-Warrant-Backing-Rebuttal (C-D-W-B-R). Meanwhile, the remaining 33 are just

claims and are not arguments. All groups of students were able to make arguments with the C-D pattern, where the highest frequency was in group 3 with the number of occurrences of this pattern 6 times out of 12 questions on the worksheet. Meanwhile, the argumentation pattern that appeared the least frequently was the C-D-W-B-R pattern which only appeared 1 time out of 2 questions at the decide stage, where only 1 group was able to make this argumentation pattern. Then, there was only 1 group which was able to make arguments with 3 different patterns, namely group 4 which was able to make patterns C-D, C-D-W, and C-D-W-B-R. Meanwhile, the group that showed the least pattern of argumentation was group 3. Group 3 was only able to make 1 pattern of argumentation, namely C-D. Below is a graph showing the frequency of argumentation patterns for each group of students, which can be seen in Figure 1.

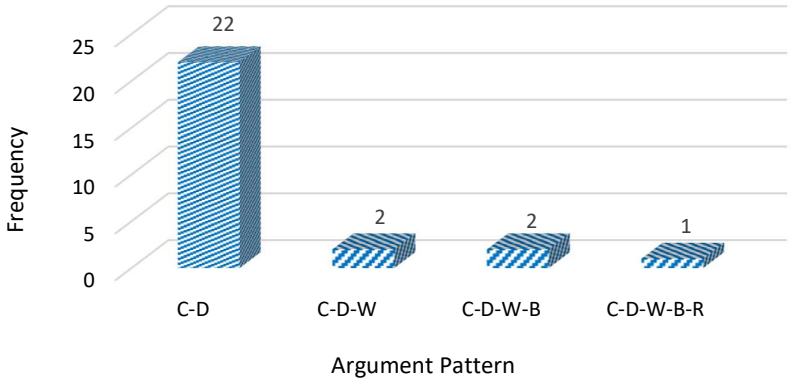
Figure 1. Frequency of argumentation patterns for each student group



Each group of students has been able to create several patterns of argumentation. Then, all the argumentation patterns that have been made by each group are added up and the patterns that appear most often can be seen. There are a total of 27 student group answers that form argumentation patterns. Based on the 27 student group answers, the one that appeared most often was C-D, namely 22 times, the C-D-W pattern 2 times, the C-D-W-B pattern 2 times, and the argumentation pattern that appeared the least was C-D-W-B-R which only appeared 1 time. For more details, an explanation of the argumentation patterns of student groups can be seen in the graph. The following is a graph that shows the overall frequency of students' argumentation patterns which can be seen in Figure 2.

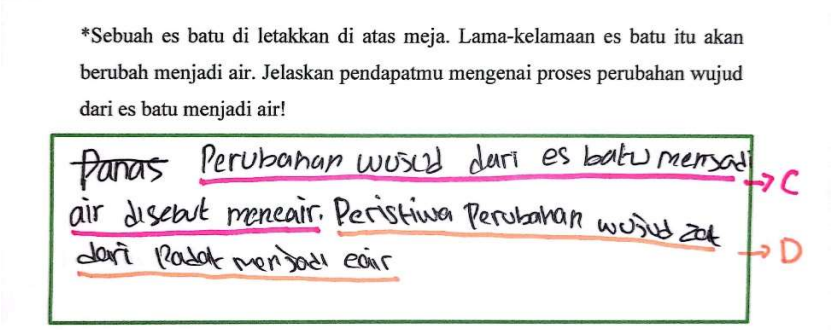
This research uses the EDP model to support students' arguments. At the define stage, students identify the client's needs and constraints to form their claim. Then, at the learn, plan and try stage, it allows students to create claims and add information in the form of data regarding science and mathematics knowledge. At the test stage, it allows students to form claims, data, and add warrants. At the decide stage, it allows students to form claims, data, warrants, as well as adding backing aspects to base the warrant and rebuttal aspects if there is an objection (Wisutama *et al.*, 2022).

Figure 2. Frequency of argumentation patterns from all groups of students



Based on the research results, students' argumentation patterns were obtained from the relationship between TAP aspects. The results of the analysis of students' argumentation patterns showed th.at there were four patterns that emerged in the students' group arguments. The first pattern is C-D which appears 22 times, namely in group 1 it appears 3 times; group 2 appeared 5 times; group 3 appeared 6 times; group 4 performed 3 times; and group 5 appeared 5 times. To find out the form of the argumentation pattern that has been written by the student, the following is an example of the C-D pattern that appears in the student's argumentation, which can be seen in Figure 3.

Figure 3. C-D pattern on a worksheet



The example above shows questions at the learn stage of EDP, where students are asked to answer questions about the melting of ice at the Earth's poles. Claim (C) that has been made by students is found in the first sentence which says,

"*The change in state from ice cubes to water is called melting*".

The indicator of a student's claim is when the student is able to write down ideas or opinions (Handayani & Sardianto, 2015). Then, the claim is supported by the data (D) in the second sentence which says,

"*The event of changing the state of a substance from solid to liquid*".

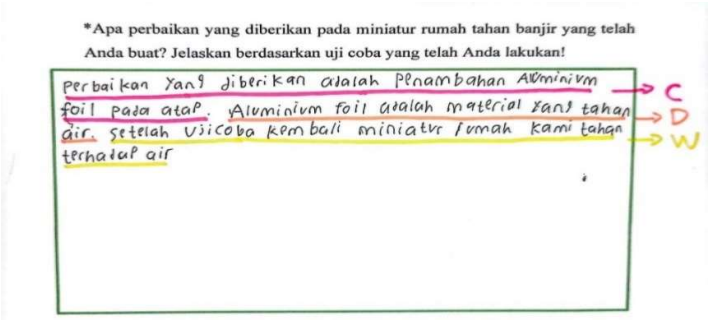
The indicator of data for students is when students are able to write down any information or evidence about their opinions (Handayani & Sardianto, 2015). This second sentence is an explanation of the melting process that students mentioned in the first sentence. Students have been able to add data (D) even though the data added is still weak. The C-D pattern is the most basic pattern that is students' initial ability to make an argument (Abduh & Sastromiharjo, 2019).

The second pattern is C-D-W which appears 2 times. This pattern only appears in the arguments of groups 1 and 4. To find out the form of the argumentation pattern that has been written by the student, the following is an example of the C-D-W pattern that appears in the student's arguments, shown in Figure 4.

The example on Figure 4 shows questions at the test stage of EDP, where students are asked to explain improvements to a miniature flood-resistant house after testing. Claim (C) that has been made by students are found in the first sentence which says,

"*The improvement provided is the addition of aluminum foil to the roof*".

Figure 4. C-D-W pattern on a worksheet



Then, the claim is supported by the data (D) in the second sentence, which says,

"*Aluminum foil is a waterproof material*".

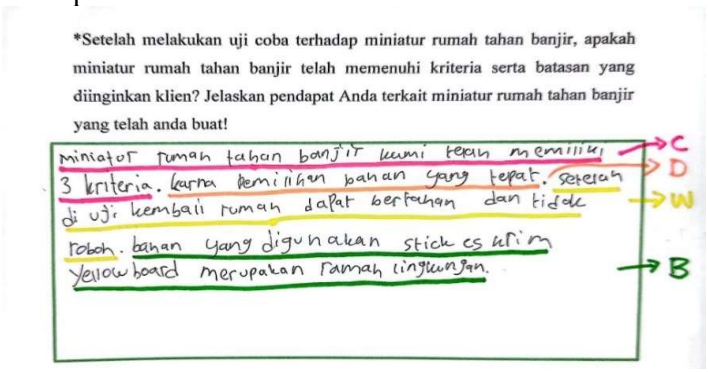
This data was obtained by students from the table provided on the worksheet. After that, the students added a warrant (W) to the third sentence, which says,

"*After being tested again, our miniature house is waterproof".*

This sentence is a warrant that functions as a link between claim and data. The indicator of a warrant among students is when students are able to write down the relationship between known evidence and write other forms of statements so that the claim is stronger (Handayani & Sardianto, 2015).

The third pattern is C-D-W-B which appears 2 times. This pattern only appears in the arguments of groups 2 and 5. To find out the form of the argumentation pattern that has been written by the student, the following is an example of the C-D-W-B pattern that appears in students' arguments, which can be seen in Figure 5.

Figure 5. C-D-W-B pattern on a worksheet



The example above shows questions at the decide stage of EDP, where students are asked to explain whether the miniature flood-resistant house they have made meets the criteria and limitations. The first sentence in the student's answer is the student's opinion/claim (C) which says,

"*Our miniature flood-resistant house already has 3 criteria*".

Then, this claim is supported by data (D), which says,

"*Because of the selection of the right material*".

This data is still relatively weak. Then, the students added a guarantee/warrant (W) which says,

"*After being tested again, the house will survive and not collapse".*

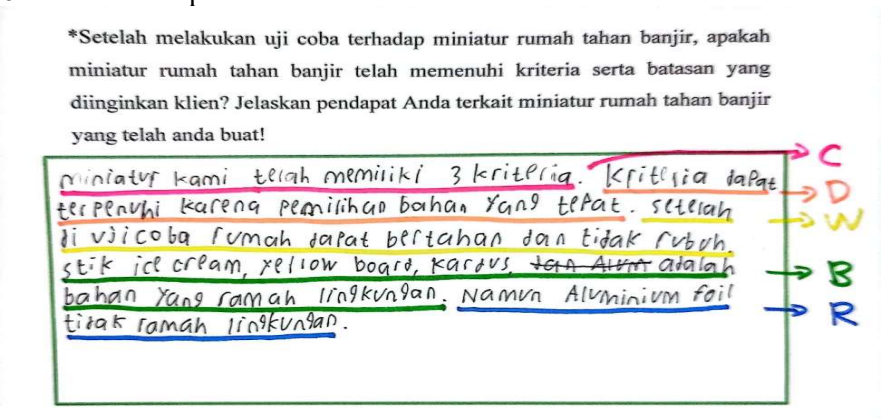
This sentence is a link between the claim and student data.Then, the previous aspect is supported by the backing (B), which says,

"*The material used is ice cream sticks, yellow board is environmentally friendly*".

The indicator of backing for students is when students are able to write stronger additional evidence to support their warrants (Handayani & Sardianto, 2015). This backing provides reinforcement that the miniature flood-resistant house has met the requirements, namely that the materials used must be environmentally friendly.

The fourth pattern is C-D-W-B-R which appears only once. This argumentation pattern is the most complex pattern from the previous pattern. This pattern only appears in group 4's arguments. To find out the form of the argumentation pattern that has been written by the student, the following is an example of the C-D-W-B-R pattern that appears in student arguments, can be seen in Figure 6.

Figure 6. C-D-W-B-R pattern on a worksheet



The example above shows questions at the decide stage of EDP, where students are asked to explain whether the miniature flood-resistant house they have made meets the criteria and limitations. The first sentence in the student's answer is the student's opinion/claim (C) which says,

"*Our miniature has 3 criteria*".

Then, this claim is supported by the data (D) which says,

"*The criteria can be met due to the selection of the right materials*".

This data is still relatively weak. After that, the student added a warrant (W) which says,

"*After being tested, the house will survive and not collapse*".

This sentence is a link between the claim and student data. Then, the previous aspect is supported by the backing (B), which says,

"*Ice cream sticks, yellow board, cardboard are environmentally friendly materials*".

This backing was then given a disclaimer/exception in the form of a rebuttal (R)

"*However, aluminum foil is not environmentally friendly".*

This example argument uses all aspects of TAP. Overall, only group 4 was able to make 3 different argumentation patterns, namely C-D 3 times, C-D-W 1 time, and C-D-W-B-R 1 time. Meanwhile, group 3 was only able to make 1 argumentation pattern, namely C-D.

The student argumentation patterns that have been made by each group are then added up and the patterns that appear most frequently are seen. The student argumentation pattern that appeared most often was C-D, namely 22 times, then the C-D-W and C-D-W-B patterns, which each appeared 2 times, and the C-D-W-B-R pattern, which only appeared once. This is in line with research conducted by Riwayani *et al.* (2019) and Abduh and Sastromiharjo (2019) which found that the C-D pattern was the pattern that appeared most

often in students' arguments. Meanwhile, the C-D-W-B-R pattern is the pattern that appears least frequently in students' arguments. One of the factors causing the C-D-W-B-R pattern to rarely appear is because students still do not understand the aspects of correct scientific argumentation (Riwayani *et al.*, 2019).

CONCLUSION

Based on the results of the research, it can be concluded that the pattern of student argumentation consists of several patterns, namely Claim & Data (C-D); Claim Data & Warrant (C-D-W); Claims, Data, Warrants, & Backing (C-D-W-B); and Claim, Data Warrant, Backing and Rebuttal (C-D-W-B-R). The C-D pattern is the pattern that appears most often. Worksheets with EDP stages can be an alternative to make it easier for students to practice argumentation skills in the classroom. However, students' argumentation abilities can still be further developed, especially in the warrant, backing, and rebuttal aspects, to form more complex argumentation patterns.

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