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# LEARNING THE CIRCULATORY SYSTEM THROUGH ENGINEERING DESIGN: INVESTIGATING STUDENTS' COLLABORATIVE PROBLEM-SOLVING SKILLS

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## Abstract

The demand for more STEM professionals calls for the incorporation of engineering practices into science learning. Moreover, many studies indicated that science lesson involving engineering activities could foster particular 21st-century skills. One of the essential 21st-century skills that can be taught and measured is Collaborative Problem Solving (CPS) skills. Numerous surveys, reports, and research studies over the past two decades revealed that this set of skills is strongly needed. However, earlier studies have not yet investigated how learning through engineering practices facilitate students with diverse learning style to acquire CPS skills. Thus, through the descriptive analysis method, this study investigates how learning circulatory system through engineering design could facilitate students with a particular learning style to perform CPS skills. Fourteen secondary students participated in the lesson unit involving a collaborative project to solve the problem through the engineering design process. Prior to lesson implementation, students' learning styles were identified using adapted VARK questionnaire. To investigate students' learning, direct observation was done throughout the lesson. Furthermore, students' discourse during collaborative work was audio-recorded and transcribed to capture collaboration skills. Students' problem-solving skills were measured by using problem-solving tests administered before and after the lesson implementation. Findings indicate that the lesson facilitated students to learn in a way that corresponds to their learning style thus enabling them to performed particular elements of CPS skills. During collaborative work, students demonstrated the varied level of collaboration skills which include participation, perspective-taking, and social regulation skills with particular trends in regard to learning style. In addition, after lesson implementation students were able to demonstrate a higher level of problem-solving skills in task regulation dan knowledge building and learning.

*Keywords*: engineering design, collaborative problem solving, science education

## Introduction

Science Technology Engineering Mathematics (STEM) education has captured extensive attention internationally. The demand of more STEM professionals in many countries has been the reason of STEM education's rapid development worldwide. Incorporating engineering into the learning is strongly suggested as it provides catalyst for integrating STEM education and making it more relevant to students' everyday experiences (Vest, 2009). In addition, the use of engineering design is found to be beneficial in supporting the development of 21st century skills (Guzey et al., 2016).

Assessment and Teaching of 21st Century Skills project explored the 21st century skills that could be taught and learned which includes critical thinking, problem solving, decision making and collaboration skills that can be combined into a set of skills called collaborative problem solving (CPS) (Griffin & Care, 2015). CPS has been identified as a particularly promising task that includes social and cognitive skills, and that can be analysed in classroom environments where skills are both measurable and teachable (Hesse et al., 2015). CPS has attracted increased attention as numerous surveys, reports, and research studies over the past two decades revealed that this set of skill is strongly needed (Fiore et al., 2017).

CPS skills might be fostered through engineering practices. As Housholder & Hailey (2012) suggests that engineering activities relies more on social involvement, cooperation and collaboration to solve the problems. In engineering design-based science, regardless the approach which is used, activities done by students always involve constructions of physical product as a mean to solve human problems (Marulcu & Barnett, 2016; Wendell & Rogers, 2013) and involve collaborative work as a team instead of individuals (Wendell & Rogers, 2013). However, earlier studies have not yet investigated how instructional strategy with engineering design-based science accommodates students' needs in terms of their learning style, especially in helping them to acquire CPS skills. In light to that, this study aims to investigate how middle school students with different learning style engage in the lesson involving engineering design activity and how it help them demonstrate particular CPS skills differently.

## Literature Review

Collaborative problem solving are a set of skills combining critical thinking, problem solving, decision making and collaboration skills (Griffin et al., 2015) that has cognitive and social domains (Hesse et al., 2015). Collaborative problem solving consists of problem solving and collaboration as its constituent terms where problem solving serve as the cognitive domain and collaboration serve as the social domain. Griffin (2015) describes that collaboration is the activity of working together to reach a common goal where communication, cooperation and responsiveness are used as the building blocks. On the other hand problem solving is defined as the activity where student aware that there is discrepancy between current situation with desired situation or goal in which the discrepancy need non-routine solution thus motivating student to perform particular action in order to achieve the goal. According to those definitions, Griffin et al., (2015) defined collaborative problem solving as "*a joint activity where dyads or small groups execute a number of steps in order to transform a current state into a desired goal state*".

The addition of collaboration provides more advantages compared to individual problem solving. Collaboration allows for effective division of labour, incorporation of information from various perspective, experiences and sources of knowledge and enhances creativity and quality of solutions through stimulation from other's idea (OECD, 2017). Therefore, through collaboration students could perform more effective and efficient problem solving with the help from others.

According to ATC21S framework of collaborative problem solving skills developed by Hesse et al. (2015), the social skills comprises of three sub skills namely participation, perspective-taking and social regulation where each sub skills consists of several elements.

Furthermore, Hesse et al. (2015) refer cognitive skill in collaborative problem solving skill as ways in which problem solvers manage a task at hand and the reasoning skills that they use. There are two sub skills of cognitive domain namely task regulation and knowledge building and learning skills.

Engineering design can be defined as the essential action of engineering that apply science and employ cognitive reasoning, mental model and operation to construct prototype or model of solution for authentic problem. Constructing prototype or model of the solution is undertaken to create a new technology that can solve the problems and eventually improve lives.

In engineering design-based science, learning activities done by students always involve constructions of physical product as a mean to solve human problems (Marulcu & Barnett, 2016; Wendell & Rogers, 2013). Moreover, the activities always involve collaborative work as a team instead of individuals (Wendell & Rogers, 2013). Engineering design is not merely about designing technology as a solution to a problem, but rather it often require the iterative processes that needs engineering thinking based on scientific laws or theories (King & English, 2016). Therefore it can be said that science learning with engineering design provide opportunities for students to work collaboratively in solving the problem that involve iterative processes applying scientific laws or theories.

While there are many version of engineering design process used in previous study, this study used Engineering Everywhere Engineering Design Process (EDP) (Higgins et al,. 2013) which is developed for middle school students. This version of EDP is the expansion of Engineering is Elementary's EDP for elementary school-aged children that previously developed and rigorously tested. The middle school version includes three additional processes, namely identify, test and communicate. The addition aims to provide more aged appropriate skills for middle school such as more autonomy to take ownership of the problem, value and apply data, and share their knowledge. There are eight steps of Engineering Everywhere EDP namely (1) identify, (2) investigate, (3) imagine, (4) plan, (5) create, (6) test, (7) improve, and (8) communicate.

It is important to remember that each student is unique individual. Thus, ensuring that the instructional strategy accommodates varied students' need in terms of how they learn best is important. It is because students who are taught in ways that fits preferred learning styles can be expected to enjoy learning and have better academic achievement (Shaughnessy, 1998). Similarly, Fleming (2006) also emphasizes that knowledge of, and acting on, one's modal preference is an important condition for improving one's learning.

Learning style can be defined as a way that a student use to perceive, interact and respond to stimuli in the environment that contributes to his or her achievement. Here, perceiving, interacting and responding refer to understanding the learning materials as its stimuli. There are many learning style models that can be identified from earlier studies such as learning styles models by Felder-Silverman, Dunn and Dunn, Kold, Honey and Murnforn, and VARK (Visual, Aural, Read or Write and Kinaesthetic). However, one of the most commonly used model is VARK learning style model which is the modification of the most accepted understanding of VAK (Visual, Auditory and Kinaesthetic) learning style. The addition of 'R' category is due to Neil Fleming's research finding reveals that there is distinction between the ability of some students who work with symbolic or graphic material compared with those who work easily with text material (Fleming & Mills, 1992). Therefore, Fleming classified the way students learn into four different modes based on different senses, namely visual, aural, reading (and writing) and kinaesthetic.

Fleming (1995) further described that there is no student who is restricted to only use one mode in learning, even so there are some dominant and minor preferences. Therefore, Fleming suggested that there are people who have multimodalities in learning., which include bimodal, tri-modal or quad-modal.

The integration of engineering design into science lesson may accommodates students diverse learning style as students engaged in activities involving the use of multiple sensory. Collaboration may facilitate students with aural learning style through opportunities to speak their ideas up as well as listen to others. The use of representation in designing solution might facilitate visual learner to build understanding on particular science concept. Students with read and write preference would also be facilitated in investigate step where they can read references to brainstorm solutions. On the other hand kinaesthetic students might be facilitated through hands-on activities during creating and testing steps. Therefore, this study aims to confirm these assumptions and further investigate how engineering based science lesson could facilitate students with diverse learning style to perform particular CPS skills.

## Methodology

Through descriptive analysis method this study analyse and describe how students' diversity in terms of learning style is facilitated through engineering design instruction as seen from particular CPS skills that students performed.

### Location and Subject

This study took place in Bandung, a capital city of west java Indonesia. The research subjects are a class of fourteen eight-grade students in one of private school in Bandung Barat area. Prior to the treatment, the students have learnt about blood circulation system but not yet learnt about disease in blood circulation system. The data collected before, during and after the implementation of engineering design project in blood circulation system topic were obtained from questionnaire, observation, and tests.

### Data Collection and Analysis

The data of students' learning style is obtained through questionnaire. The questionnaire is adapting VARK (Visual, Aural, Read and write, and Kinaesthetic) questionnaire for young learner version 7.1 that can be found on www.vark-learn.com. VARK questionnaire consists of 16 questions reflecting situation in everyday life. Each question followed by four different options, each corresponds to one type of learning style either visual, aural, read and write or kinaesthetic. The VARK questionnaire was adjusted to make it more relevant for the research subject. Since the original version use English, the adjustment was made by translating the questionnaire into Indonesian language so that students can comprehend the questions and its options. Thus allowing them to give responds that really reflect their learning style. Based on the score on each learning style category, students will be assigned into two categories: single modal learner (either V, A, R or K only) or multimodal learner (have two or more learning styles). To determine the learning style of each student, the data obtained from VARK questionnaire is analysed based on VARK questionnaire scoring guidance (Fleming, 2006).

The second data is students' collaborative problem-solving skills on social domain. Students' collaboration skills were measured through direct observation with performance assessment rubrics. The rubrics were developed by adapting CPS framework on social domain (Hesse et al., 2015). In this study, observed behaviour indicating particular elements in the three subs kills was rated ranging from 1 to 3 points. Prior to its use, the observers tried to read the observation rubric and did discussion about example of action indicating each element of collaboration skills. This was done to ensure that all observers have the same interpretation. The observation not only be done during students' learning using engineering design project but also be done on the previous lesson involving collaborative activities, thus allowing for analysis of initial and final profile of students' collaboration skill.

On the other hand, students' collaborative problem solving skills on cognitive domain was measured through written test consisting nine structured questions. The test was done before and after lesson implementation. The test items along with its marking scheme were developed based on adaptation of CPS framework on cognitive domain (Hesse et al., 2015).

Prior to its use, problem solving test instrument was validated by two research supervisors and analysed based on trial results. The test items fulfilling good criteria and test items requiring minor revisions were selected to be used in pre-test and post-test. The results of instrument trial was analysed by Anates V4 program prior to its use to measure validity, reliability, level of difficulty and discriminating power of test item.

## Results and Findings

After identification of learning style (Table 3), it was found that students have varied learning style, which include single-modal (57%), bi-modal (29%) and tri-modal learning style (14%). The details of students' learning style can be seen on Table 1.

Table 1
*Students' Learning Style*

| Students' Learning Style | Modality | Number of students | % |
|---|---|---|---|
| Single-modal | V | 1 | 57 |
| | A | 3 | |
| | R | 2 | |
| | K | 2 | |
| Bi-modal | VA | 3 | 29 |
| | AK | 1 | |
| Tri-modal | ARK | 1 | 14 |
| | VAR | 1 | |
| TOTAL | | 14 | 100 |

Observation results and coded transcribed audio recording indicate that students performed collaboration skills during learning circulatory system through engineering design practices. Data implies that the average score of participation skills were the highest compared to the other two subskills. This finding suggests that the students demonstrated active engagement in the learning involving engineering design practices. It is not surprising as Marulcu & Barnett (2016) express that when engineering is used as context for science learning, students can be more motivated and engaged to learn.

Table 2
Students' Score on Elements of Collaboration Skills

| No | Student | Learning Style | Elements of Collaboration Skills | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **P1** | **P2** | **P3** | **PT1** | **PT2** | **SR1** | **SR2** | **SR3** | **SR4** |
| 1 | A1 | A | 8 | 9 | 9 | 8 | 6 | 9 | 1 | 0 | 9 |
| 2 | A2 | A | 7 | 9 | 7 | 8 | 6 | 8 | 2 | 2 | 8 |
| 3 | B1 | AK | 9 | 9 | 8 | 8 | 7 | 8 | 0 | 2 | 9 |
| 4 | B2 | VA | 9 | 9 | 9 | 8 | 7 | 8 | 0 | 0 | 8 |

| No | Student | Learning Style | Elements of Collaboration Skills | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **P1** | **P2** | **P3** | **PT1** | **PT2** | **SR1** | **SR2** | **SR3** | **SR4** |
| 5 | C1 | VA | 9 | 9 | 9 | 8 | 7 | 9 | 4 | 4 | 8 |
| 6 | C3 | K | 8 | 8 | 6 | 6 | 6 | 6 | 0 | 0 | 7 |
| 7 | D1 | A | 8 | 9 | 9 | 9 | 7 | 8 | 2 | 0 | 6 |
| 8 | D2 | ARK | 9 | 9 | 9 | 7 | 8 | 9 | 3 | 2 | 8 |
| 9 | D3 | V | 9 | 9 | 9 | 7 | 7 | 8 | 1 | 3 | 8 |
| 10 | D4 | R | 9 | 8 | 9 | 7 | 5 | 6 | 0 | 0 | 8 |
| 11 | E1 | VAR | 9 | 9 | 9 | 7 | 8 | 9 | 0 | 0 | 8 |
| 12 | E2 | VA | 9 | 9 | 9 | 7 | 9 | 8 | 5 | 3 | 8 |
| 13 | E3 | K | 8 | 9 | 6 | 6 | 6 | 9 | 2 | 1 | 7 |
| 14 | E4 | R | 7 | 7 | 7 | 7 | 6 | 6 | 0 | 0 | 5 |
| | Element Average | | 8.4 | 8.7 | 8.2 | 7.4 | 6.8 | 7.9 | 1.4 | 1.2 | 7.6 |
| | Subskill Average | | | 8.43 | | 7.10 | | | 4.53 | | |

As we look closer, Table 2 illustrates that almost all students is actively engaged in the lesson independently as indicated by high level of action (P1) elements. Most of the students also demonstrate high level of interaction (P2). This finding implies that they were able to not only respond to communication but also initiate interaction. However, E4 student with single-modal read/write learning style had the lowest score compared to others. From the transcribed recording, it was found that E4 only able to respond to cues in communication. According to the results of VARK questionnaire, it was found that E4 student has lowest score on aural preference, which indicates that her preference to speak up expressing ideas or opinion is low compared to others. An interesting finding was found on P3 element where students who have kinaesthetic learning style only able to performed middle level of the skills. These students tend to play with the learning materials and forget to finish the main tasks that eventually inhibit the collaboration process within the group. Pang et al., (2018) voice similar findings where it is found that students often experienced challenges in collaborative learning which include levels of teamwork, communication amongst group members, personal priorities and external constraints.

The score on adaptive responsiveness (PT1) element in each meeting illustrates that students who has aural modal in their learning style tend to perform higher level of adaptive responsiveness compared to those without aural modality. More interesting finding were found on audience awareness (PT2) elements, where there is more distinct pattern differentiating students with different type of learning style. Analysis of PT2 score on each meeting reflects that students with tri-modal learning style perform better audience awareness as compared to the others. Those with bi-modal learning style and single-modal learning style as the poorest follow it. A possible explanation for this might be due to multimodalities that they have, where students with tri-modal and bi-modal learning style able to make their explanations comprehensible to others by adjusting the way they communicate to be appropriate with the way others understand. Multimodal students are flexible and able to switch from mode to mode depending on what they are working with or the situation they are dealing with (Fleming, 1995).

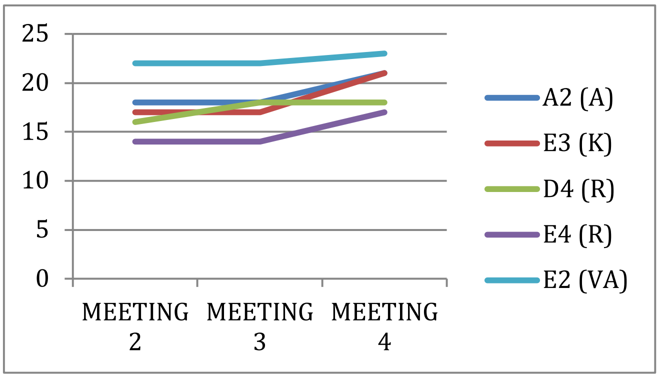
Varied performances are found in the elements of social regulation skills. All students able to perform negotiation due to the existence of varied perspective among the students when they engaged in engineering design process, especially during planning and creating. Students often came up with diverse opinions and strategies that rise conflict among group members. As conflict arouse, students were pushed to negotiate the steps or ways that accommodate the differences between individual approaches (Hesse et al, 2015).

The students' score on negotiation (SR1) element indicates that D4 and E4 students who have single-modal read/write learning style only able to perform middle level of negotiation as they negotiate to reach common understanding. The same thing demonstrated by C3 student with single-modal kinaesthetic learning style. The rest of the students, including single-modal visual, single-modal aural and multimodal learners were able to not only negotiate to reach common understanding but also to achieve resolution of differences that refer to high level of negotiation

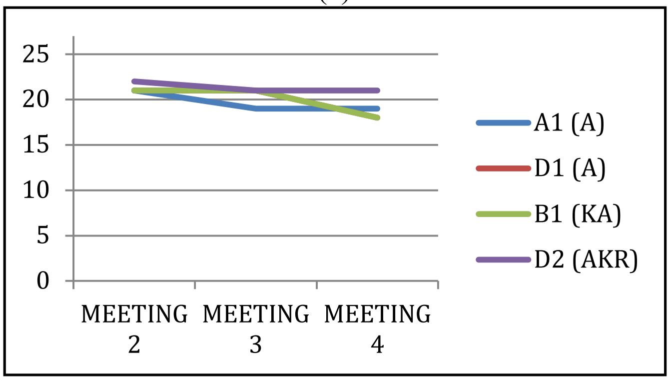
The next two elements of social regulation skills, metamemory (SR2) and transactive memory (SR3), refer to the ability of recognizing group diversity (Hesse et al., 2015). As compared to other elements of collaboration skills, students' performance on these two elements were the poorest. The scores indicates that only several students able to show either low level of metamemory or low level of transactive memory. Supposedly, students could recognize one's and others' strengths and weaknesses during collaborative work. It is because within collaborative work students communicate ideas one to the other. This communication provides transactive memory system that builds on metamemory, which let each members of the group to obtain more and better knowledge of others' expertise (Wegner, 1986). However, without making utterance acknowledging one's expertise or strengths and weaknesses, these two skills were not observable in this study. There are several possibilities of why these two elements are underperformed. First, the lesson with engineering design in blood circulation system somehow did not accommodate all students to express group diversity in terms of one's and others' strengths and weaknesses. Second, codes of etiquette in Indonesia might differ with other countries in which the indicator of collaboration skills is developed. Indonesian people tend to embarrassed easily and it is considered very rude to deliberately mention or describe other's weaknesses. In addition, showing off strengths of oneself often regarded as arrogant. These Indonesian cultures might cause students to be reluctant in expressing strength and weaknesses of himself or others. Nonetheless, from the SR1 and SR2 score on Table 4.2, it can be said that most of the students who have aural preference, having either single or multimodal learning style, were able to express strength or weakness of oneself or express strength or weakness of others. At least they are able to note owns or others' performance. At most they are able to give comments on appropriateness of owns or others' performance.

For responsibility initiative (SR4) element, pattern of how students perform this element in regard to their learning style cannot be identified. However, it can be said that most of the students with various learning style were able to show responsibility by ensuring parts of group task are completed by regularly monitoring group progress. This is due to the nature of engineering activities which is student driven that encourage students to take charge of their learning. The learning which enables students to take charge of their own learning will give opportunities for the students to monitor procedures in achieving the goal and to evaluate the achievement (Holec in Yuliani, 2017).

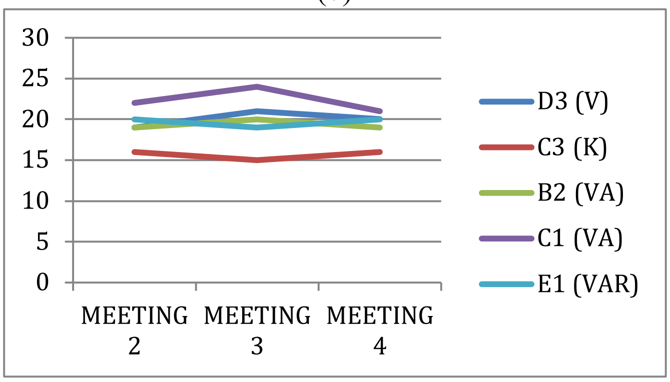
Further analysis was done to figure out whether there is particular trend of students' collaboration skills along their engagement in the engineering design project. Results shows that the class average of collaboration skills score was slightly increased over time. The lowest average score was found in Meeting 2 while the highest average score was found in Meeting 4. However, the individual trends of collaboration skills were varied. The trend of students' collaboration skills can be seen on Figure 4.4.




(a)




(b)




(c)

*Figure 1.* Trends of Collaboration Skills Score along learning through ED
(a) Ascending trend dominated by students with single modal learning style
(b) Descending trend dominated by students with aural learning style
(c) Fluctuated trend dominated by students with visual learning style

After the engagement in the learning of blood circulation system with engineering design, students showed better performance in problem solving skills. Table 3 presents the students' performance in each elements of problem solving skills after they learn blood circulation system with engineering design practices.

Table 3
*Students' Performance in Elements of Problem Solving Skills*

| No | Student | Learning Style | Elements of Collaboration Skills | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PA | GS | RM | FA | CEI | S | R | CE | H |
| 1 | A1 | A | 3 | 3 | 2 | 3 | 3 | 3 | 2 | 2 | 3 |

| No | Student | Learning Style | Elements of Collaboration Skills | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PA | GS | RM | FA | CEI | S | R | CE | H |
| 2 | A2 | A | 2 | 2 | 3 | 3 | 1 | 3 | 3 | 3 | 1 |
| 3 | B1 | KA | 2 | 2 | 3 | 3 | 2 | 2 | 3 | 3 | 3 |
| 4 | B2 | VA | 2 | 3 | 2 | 1 | 2 | 2 | 3 | 2 | 1 |
| 5 | C1 | VA | 2 | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 3 |
| 6 | C3 | K | 2 | 2 | 1 | 1 | 1 | 2 | 3 | 2 | 1 |
| 7 | D1 | A | 2 | 3 | 2 | 1 | 1 | 3 | 3 | 2 | 3 |
| 8 | D2 | AKR | 2 | 2 | 2 | 1 | 1 | 3 | 2 | 3 | 1 |
| 9 | D3 | V | 2 | 2 | 2 | 2 | 2 | 3 | 2 | 2 | 3 |
| 10 | D4 | R | 3 | 0 | 0 | 1 | 1 | 3 | 3 | 3 | 1 |
| 11 | E1 | VAR | 3 | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 1 |
| 12 | E2 | VA | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 | 3 |
| 13 | E3 | K | 2 | 2 | 3 | 1 | 2 | 3 | 3 | 3 | 1 |
| 14 | E4 | R | 0 | 0 | 1 | 2 | 0 | 2 | 2 | 2 | 1 |
| Average | | | 2.07 | 2.00 | 1.86 | 2.00 | 1.71 | 2.64 | 2.64 | 2.57 | 1.86 |

Students' shows better performance in problem analysis (PA), regardless their learning style, after they engaged in the lesson. This finding is in line with studies done by Yanyan et al. (2015) who found that engineering design-based pedagogy did help students' ability to analyse problems. *Identify* part in engineering design process provide more stimuli to this element. As mentioned earlier, in *identify* process students were required to analyse a passage containing ill-structured problem until they were able to state the problem in question form. However there is an exception which is found in E4 student with read/write learning style who still cannot perform problem analysis. According to audio transcription it is found that during identify process students with read/write learning style, including E4 student, did not involve in the discussion to determine problem statement. Instead, she only copied problem statement written by her friends.

Generally students performed middle level of goal setting. It is indicated by their ability to state specific goal. Moreover, there were four students who were able to perform high level of goal setting. Those are A1, B2, D1 and E1 students with aural (A), visual-aural (VA), aural (A) and visual-aural-read/write (VAR) learning style respectively. There is common characteristic that can be identified from these students, that is all of them have dominant aural modality in their learning style. As elaborated earlier, the audio transcription illustrates that those who involved in the discussion actively during determining goal of the project were those who have aural preference.

Students performed varied level of resource management skill, ranging from low, middle to high level. Hesse et al (2015) argue that when students engaged in collaboration activity to achieve particular goal, they need a shared plan which includes the management of resources. The acts of managing resources were evident when students shares knowledge one to the other, manage constructions materials, and divide workloads.

The data also implies that all students were able to perform flexibility and ambiguity skills with various levels. The diversity of students' score in this element of problem solving skills indicates that it is unlikely that particular type of learning style performed better or worse in flexibility and ambiguity skills. Nonetheless, all of the students showed improvement in this skill. It is due to the fact that the engineering design processes that the students had through provide benefit of design thinking (Mangold & Robinson, 2013). Design thinking is characterized by a set of skills that include tolerating ambiguity and dealing with uncertainty (Dym et al., 2005).

More observable pattern was found in collect elements of information (CEI). According to CEI score on Table 4.8, it was found that students with multimodalities tend to perform better compared to those with single-modality. Students with tri-modal learning preference were able to perform high level of the skill, while students with bi-modal learning preference were mostly able to perform middle level of the skills. While low level of the skill were dominantly performed by those with single-modal learning style. *Investigate* step provide more stimuli to this element of the skills. It is because during investigate step students need to gather the information to solve problem (Higgins et al., 2013).

The score of sistematicity elements on Table 4.8 indicates that generally students were able to perform middle to high level of sistematicity as many of them able to described sequence of action to solve problems. It is possible because as the students involved in engineering design activity they were required to think and act systematically along the process. Views from Eide et al. (in Syukri et al., 2018) support this finding as he said that the engineering design process is actually a problem-solving activity through developing idea or product that requires creative thinking in a systematic way.

Similarly, regardless the type of learning style, students able to perform middle to high level of skills in relationship (R) and rules of cause and effect (CE). It is indicated by students' ability to identify connections between elements of knowledge as well as use understanding of cause and effect to develop a plan in solving problem as they choose the best possible solution followed by giving relevant reasons. It can be explained by the fact that the practical approach used in engineering design process helps students to discover relationship between scientific concept with technology, problem solving and design.

For hypothesis (H) element, the score presented on Table 4.8 illustrates that students were able to perform either low or high level of hypothesis. This finding implies that after engagement in the learning of blood circulation system with engineering design-based project, students were able to adapt and apply reasoning to suggest solution for problem in different context. It is because engagement in engineering design process trained students to transfer or apply their knowledge to particular situation in achieving the desired situation. Engineering itself is defined as the action to improve lives by transforming the world in such a way through applying the knowledge (Bagiati & Evangelou, 2016). In this case, students applied their knowledge about science concept related to blood circulation system to solve problem through engineering practices. As Yanyan et al (2016) explained, engineering is the application of science to solve problems. The distinctive finding that can be identified is that students with single-modal read/write learning style only able to suggest solution for other relevant problem without giving any reason. The rest of the data did not suggest for particular pattern in regard to type of learning style that students have.

## Conclusion

The lesson unit of blood circulation system using engineering design facilitate students with diverse learning style to demonstrate and develop collaborative problem solving skills. Collaboration skills were evident as observed from all students with varied learning style. Further analysis revealed that students with aural preference and multimodalities tend to demonstrate better performance in particular elements of the skills, such as adaptive responsiveness and audience awareness as compared to the others.

However, the data obtained from this study implies a very limited understanding about particular pattern of students' performance in problem solving skills in regard to their learning style. The most distinct tendencies were only found in goal setting (GS) and collect element of information (CEI) elements. Firstly, students who have aural preference, either as single-modal or multimodal learning style, tend to perform better on goal setting element as compared to students who lack of aural preference. Second, students with multimodal learning style tend to perform better than single-modal learner on collecting element of information. In addition, analysis also resist that students lack involvement in identify step of engineering design process lead to low performance in corresponding problem solving skill elements such as problem analysis and goal setting element.

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