Research Article

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Hands-on Learning In STEM: Revisiting Educational Robotics as a Learning Style Precursor

Abstract: The importance of learning style in student's learning performance has been gaining scholar's attention since it was coined in the early 70s. Atmatzidou's robotics procedure of a five-stages robotic activities was deployed in the research. This study adopts a case study research design for gathering and analyzing data as the case research allows the exploration of unforeseen phenomena and offers insights into the interdependencies among components revealed in the study. This research introduces the use of Lego Mindstorm as the mean of profiling a student's behavioral patterns. Student's behavior patterns, then, mapped into radar charts to present the extent of both Kolb and science, technology, engineering, and math (STEM)'s profile of student's learning style categories. The paper contributes to theory by extending Kolb's Learning Style instrument by mapping the pattern of learning styles identified in the research and exploring students learning experience. Dominant four-domain-indicators captured during the activities characterize Students' learning profiles. While the Kolb Learning Style and its instrument are considered classic in hands-on literature, the use of educational robotics to elaborate students' learning style is novel in the literature that may affect the delivery of non-technology subjects in the curricula.

Keywords: Educational robotics; Kolb learning style; Hands-on learning; STEM teaching and learning

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1 Introduction

The importance of learning style in student's learning performance has been gaining scholar's attention [1–3] since it was coined in the early 70s. Kolb Learning Style [4], for example, illustrates four unique characteristics of an individual's learning style, namely accommodating, assimilating, diverging, and converging. Those characteristics are highly intercorrelated to the extent that a feature may come up as a combination of two adjunction indicators.

Different from personality cognition abilities that rely on learners' psychomotor speed, motor-cognitive flexibility, and attitudinal flexibility [5], Kolb's experiential learning style conceptualizes the variety of learners experience influences the way knowledge is constructed. The issue may arise as an understanding of students' specific learning styles may not be readily recognized by teachers. While students' attention significantly affected the efficiency of acquiring knowledge [6] teaching and learning processes would be problematic without a decent understanding of student's specific learning styles.

It is acknowledged that teachers play a prominent role in encouraging students into science, technology, engineering, and math (STEM) [7]. Teachers' engagement during the STEM delivery would likely influence students' interest in STEM and their pursuit of a STEM career. Indeed, teachers should be better informed about the need for science literacy to a certain extent [8] especially for advising underserved students on science courses.

Scholars advocate robotics as promising pedagogical means that potentially increase student's cognition in Science, Technology, Engineering, and Math (STEM) [9, 10]. It is argued that mechanical and programmable components of robotics reinforce learning and collaboration through authentic project design [11]. The research question posed to the inquiry is how learning styles could create a certain learning experience in hands-on robotics STEM activities.

2 Theoretical Foundation

2.1 Kolb Learning Style

Through questionnaires, data can be used to identify trends in the learning styles of each student. According to David Kolb [12], identification of trends in student learning styles is carried out with the following characteristics:

a) Activist is another word for Active Experimentation, Reflector is another word for Reflective Observation, Theorist is another word for Abstract Conceptualization, and Pragmatist is another word for Concrete Experience.

b) According to Kolb, learning styles consist of the way students do things and the way students think about a particular situation. The method of doing things comprises Activist and Reflector, while the way to think of something categorized as Theorist and Pragmatist.

c) A specific pattern represents the tendency of a student's learning style, whereas Kolb also has its profile in the mapping of numbers that indicate the character is at the level of very weak-medium-strong-to very strong.

d) Learning style was determined based on the two most important trends from the results of the questionnaire that students have filled out, those either Activist or Reflector and Theorist or Pragmatist.

2.2 Educational Robotics in STEM

Educational Robotics is an interdisciplinary activity drawing on Science, Maths, Informatics, and Technology [13]. Rooted in the theoretical perspective of Piaget's constructivism, Papert's constructionism, and Vygotsky's collaborative learning, Educational Robotics encourages students to actively developing many mental skills and creating new knowledge. The significant benefits it may entail are suitable for learners of all levels [14]. It has been indicated that educational robots are positively affecting the development of critical thinking, problem-solving, and metacognitive skills [15] and also proficiency in a programming language. Besides, the most significant advantage of using robots is the ability to turn abstract concepts into real-world problem solutions [16].

Robotics has been becoming a new learning media that innovates the channel of knowledge and teaches the understanding of expertise upon reality to people outside of science. Robotics best convey the design, build, operate, and the use of robots and computers as control, sensors, and information processors. Robotics would become a significant material for computational thinking since it facilitates the requirements of technology provision, including intelligence, embodiment, and enables interaction between learners and the interaction media [17]. Deploying robotics in learning will introduce learners to new, creative, and innovative technologies. Learners will be exposed to a new mindset in the active creation of technology rather than being passive consumers of technology [18].

3 Research Methodology

3.1 Research Procedures

This research emphasized the use of Lego Mindstorm as the module for students' robotic activities. A case study research method [19, 20] was designed for gathering and analyzing data. The case research approach enables the exploration of phenomena and offers insightful meaning over factors captured in the study. It is believed that case study research will be the most appropriate technique in gaining in-depth knowledge of the practices of using robotics in an educational setting.

Researchers encouraged students to join the procedure to assembly and program the Lego Mindstorm Home Edition. The robotics workshop procedure that was administered into five stages. The research stages are outlined as follows:

3.1.1 Stage 1: Preparation

Once time slot nominated, 39 participants were assigned with robotics activities time slot in the laboratory. The activities began by filling out a Kolb questionnaire, which was useful for profiling each participants' learning styles. Soon afterward, the participants were introduced to Lego Mindstorm robotics assembly, Lego Mindstorm programming, and an overview of STEM teaching and learning. The participants grouped under an individual's learning styles profiled from the filled questionnaire.

3.1.2 Stage 2: Introduction

Participants were introduced to the Lego Mindstorm and its components. Researchers described the components' names and functions briefly. The terms were introduced

Table 1: Participating students' characteristics

Student	Indicator 1	Indicator 2	Learning Style
Student A	*Active Experimentation* (*Activist* – very strong)	*Abstract Conceptualization* (*Theorist* - medium)	Converging
Student B	*Active Experimentation* (*Activist* - strong)	*Abstract Conceptualization* (*Theorist* - weak)	Converging
Student C	*Reflective Observation* (*Reflector* – strong)	*Abstract Conceptualization* (*Theorist* – medium)	Assimilating
Student D	*Active Experimentation* (*Activist* – very strong)	*Concrete Experience* (*Pragmatist* - weak)	Accommodating
Student E	*Reflective Observation* (*Reflector* – strong)	*Concrete Experience* (*Pragmatist* - medium)	Diverging
Student F	*Active Experimentation* (*Activist* – medium)	*Concrete Experience* (*Pragmatist* - weak)	Accommodating
Student G	*Active Experimentation* (*Activist* – strong)	*Concrete Experience* (*Pragmatist* - weak)	Accommodating
Student H	*Active Experimentation* (*Activist* – very strong)	*Concrete Experience* (*Theorist* - weak)	Converging

to inhibit participants' confusion upon components' terminology and capabilities. The research utilized Lego Mindstorm's main components such as sensors, bricks, beams, and large and medium motors. Researchers also introduced the Lego Mindstorm Home Edition programming language to the participants. Upon this stage, researchers began to observe the participants' behavior, particularly on the participant's first impression of the learning media.

3.1.3 Stage 3: Assembly

Each group of participants assembled their robots according to electronic modules prepared beforehand. Researchers observed students' behavior by the Kolb learning style and STEM learning indicators. Also, due to time constraints at this stage, there are breaks at certain times to adjust prayer times and lunch.

3.1.4 Stage 4: Completion and result testing

Participants were allowed to test the results of the robot sequence that has been completed. Each group tested and played along if there is still time left. This programming phase encouraged participants to test various programming commands on their robots.

3.1.5 Stage 5: Closing and reflecting

In the last step, the researcher concluded the activity before conducting the interview sessions. It is considered significant for researchers to adjust the interview questions according to an individual's learning style indicated in Kolb questionnaires. Due to the participants' experience, the researchers anticipated a change in participants' perceptions over robotics activities concerning the subject under investigation. For practicality reason, only 8 of the participants were interviewed, wherein those expressing they were keen to be interviewed. While the interview protocol prepared beforehand as an open-ended interview [21, 22] the follow up questions may be different for individual participants.

3.2 Data analysis

Before corroborating with the study of the interview text and observation sheet, the first phase of the research carried over questionnaire responses to map students' learning style tendencies. Kolb's Learning Style instrument [12] was administered to facilitate student's self reflect on their learning tendency either Activist or Reflector and Theorist or Pragmatist. The pattern elucidated from the questionnaire, then plotted into a learning style radar chart. The insight over the individual's learning style, subsequently, elaborated with the result of qualitative data analysis [23] derived from interview transcripts and observation sheets.

4 Result and Discussion

Analysis of the interview data reveals the insight into students' learning achievement. Of particular researchers' interest is the behavioral pattern of students during engagement in STEM learning. An overview of the themes is presented in the following sub-chapters. The profile of topics, then, examines for consistencies with Kolb's learning style indicators.

4.1 Develops Student Enthusiasm in STEM Learning

Growing enthusiasm is of critical importance both in the learning process and the workplace [24]. It consists of work involvement that includes students' personal experiences

to be needed in learning activities. Enthusiasm can produce inspiration in ideas and actions as well as higher motivation to learn [25]. So that enthusiasm becomes one of the achievements of the learning process because it can influence student learning outcomes. However, in STEM, learning enthusiasm may be expressed differently from one learning style to the others.

The design of robotics STEM learning was a combination of interactive and collaborative learning activities. According to data analysis, students' enthusiasm triggered by robotics activities per the following characteristics:

Complex Activities Intensifies Student's Attention

Students assemble robot models using Lego Mindstorm. Those are the independent activities involving programming to insert instructions to the built robots. Like for example what was stated by student B who had the characteristics of converging when asked to express about learning using Lego Mindstorm,

"The activities (involving robotics) were way more difficult and complicated, but exciting. "(Student B).

Relevant to Kolb's [12] finding, of the characteristics of a person with a Converging learning style. Convergers tend to learn something from the activities they are involved in. They are supporting observation on student A, which shows the results when students without hesitation took the Lego component directly while following the directions in the module.

Whereas students with Accommodating learning styles tend to like the dynamics of an activity [12]. The different pattern of events in each step of STEM learning becomes an attraction for accommodation students. As expressed by students G and students F with the characteristics of Accommodation regarding the learning patterns of STEM learning activities with Lego Mindstorm robotics,

"It is preferable that in this mix, there is a practice of rafting with the program; the problem is that at school, it keeps getting monotonous and makes me bored. I do not like the same activity carried out repeatedly."(Student G).

"Can learn while playing but can also know how to make a robot like that and know how to program it ..." (Student F).

Students are able to interact directly with the Lego Mindstorm component; occasionally, students try to assemble according to their intuitions. Moreover, when students can capture this, it becomes a new experience in viewing robots as a learning medium. Because the use of Lego Mindstorm robots in the learning process is a medium that is easily understood and reached by students [26].

On the other hand, exploration activities are shown by students Diverging learning styles to deal with the complexity of exercises. It is shown in the results of observations in the third to fifth-hour frequency, that Student E found out that the functions of the various Lego Mindstorm components that were not even mentioned in the module. Participants created a different shape with a similar purpose. Likewise, during the programming phase, rather than asking the researchers for assistance, the participating students prefer to explore the Lego Home Edition by themselves to understand it.

"I recalled the time to learn basic programming at school... "(Student E).

The answer to how students find solutions to these problems indicates that even though the diverging style student likes to work in a group [27], they sought the ways to solve problems independently. Students are able to work independently with minimum assistance of others so that problems can be solved, and they found the solutions needed.

Comparison of Past Experiences with New Concepts

Students' enthusiasm can be stimulated when there is a difference between their usual activities and new activities. The application of the robotics STEM learning was considered new things students encountered. When students are faced with new challenges, then they will find differences in the learning process with learning activities carried out before both in terms of systems, learning media, to the problems that have to be carried out.

Students with a Converging learning style tend to be able to find practical uses and are happy about new ideas in the new applications [27]. Students accustomed to Free Pascal as a learning application found out that the Lego software is the other application with similar functionality. Following is the explanation of student A regarding STEM learning with Lego Mindstorm robotics, which is his first encounter,

"It's more interesting to mix it like this. The problem is usually when you learn monotonous basic programming using only free pascal, enter the numbers... "(Student A).

They realized that many applications potentially applied as their learning tool because Converging students prefer experimental activities [12] rather than the tedious learning process that requires them to be on the same job for a long time.

Students with Assimilating learning styles, on the other hand, found it easier to understand software with a variety of images. According to Kolb [12], assimilating students tend to think first to act later. As expressed by student C who identified as an assimilating learning style when asked about using new ways of learning,

"The software is more straightforward; it wasn't too complicated either. If Pascal has to be detailed, then the (Lego Mindstorm) software display will be easier to understand ... "(Student C).

The statement is relevant to one indicator that is shared by the Assimilating and Converging learning style, namely Abstract Conceptualization. They need time to explore Lego Mindstorm Home Edition software first to be able to understand the functions of tools based on the images or symbols displayed [12]. Based on the observations, Student C, as an assimilating characteristic, shows activity at the fourth-hour frequency by repeatedly trying out functions in the Lego Mindstorm Home Edition. Students rely on symbols and images that they know. Enthusiasm was explicitly expressed during the activity as students went through problems and found the solutions in the learning process.

4.2 Robotics Provides New Experiences

The activity of using learning media such as Lego Mindstorm robotics is one of the new things for students as participants. They don't have experience with robotics or the like. This is one of the concerns for researchers to see the achievement of their enthusiasm during the STEM learning process using Lego Mindstorm robotics.

Student B with Converging learning characteristics shared his opinion on how to work on a project using the Lego Mindstorm robot,
"Arrange the collections that were collected first, well then after being assembled immediately assembled and for example, and we need help later we get something like that ..." (Student B).

Relevant to Abstract Conceptualization, which is one indicator of converging, students tend to do things technically and be able to find practical uses [27]. Even though Converging students first meet the Lego Mindstorm robot, they are able to make decision steps such as sorting components in advance so that the project works well.

Similar to Converging students, students with Accommodating learning styles have the same initial way. Following is the explanation of student G about how to work on the Lego Mindstorm robotics project,
"The small parts. So apart first, all who want to use it are then assembled ... "(Student G).

From this explanation, it can be seen if students choose to interact directly with the components used by sorting each part needed. The similarity between Converging and Accommodation students related to their interaction with the Lego Mindstorm component is an indicator

of Active Experimentation. The indicator suggests that students' work is filled with action and enthusiasm that drove their focus on what they are doing at that time [12].

4.3 Students' Familiarity with Objects and Learning Situations

Lego is an object that is familiar to students but is now with the combination of robot components in improving exploration and developing a game [28]. In this study, the use of Lego Mindstorm gave rise to a familiar feeling that was shown by all students during the activity. However, in the STEM learning process with Lego Mindstorm robotics, it shows the casual atmosphere or familiarity of students in the form of expressions or attitudes based on each characteristic of the learning style they have.

Converging students tend to feel familiar with the robot assembly and programming software used. Like the opinion of H students who have Converging characteristics regarding the use of media for the first time encountered before,
"Same with group friends gathering components first, then assemble. Everything is just spontaneous ... "(Student H).

Spontanity according to Students H is one of the self-confidence shown by students. Converging students have a strong foundation of confidence [12]. They realized that the shape of the Lego Mindstorm robot component was similar to the Lego game they had played as a child. So students tend to directly assemble relying on students' intuition with the modules provided. In addition, students are more easily adapted to the Lego Mindstorm Home Edition software because students are familiar with the visualization of symbols owned by Lego software that are similar to the functions of the Free Pascal program. For example, if represented by the function switch on Lego, infinity symbol as a loop function, and others. Converging prefers experimenting with new ideas and the use of practical applications [4].

Student E who is a student with the characteristics of diverging shows an attitude that is not much different. Like for example what was expressed by student E when asked to communicate about how to overcome the problems encountered while working on the Lego Mindstorm project in learning,
"Corrected again, see the module. I remember the time to learn basic programming at school ... "(Student E).

Similar to the thinking of Converging students, Diverging students are able to equate the functions of programming software that has previously been used with new ones. One indicator held by Diverging in the form of Re-

flective Observation shows that students are able to review the situation at hand [12] so that they can adapt to new programs more comfortably with the knowledge gained from previous experience.

While the Accommodating students were more expressing their familiarity with the Lego Mindstorm robot component. During the learning process students tend to feel that they are playing while learning. The learning atmosphere is expressed by the Accommodating students through their explanation of how to work on the Lego Mindstorm project as follows,

"I try to do it while playing, I can change the components ..." (Student F).

The concept of Lego Mindstorm components makes students seem nostalgic with childhood games. So students become easier to adapt and are familiar with the components used. Relevant to Kolb's statement [12] one of the indicators of Accommodating is Concrete Experience, where students focus on what is being done and consider these activities such as games, problem-solving, and simulations.

While Assimilating students specifically compares the two activities that take place based on the experiences that affect the process. Following are the views of C students who are characterized by Assimilating when asked their opinion about the STEM learning process using Lego Mindstorm robotics media,

"Yes, to program it is more difficult, but it turns out the pain isn't too tricky, though. Maybe because if (the programming part) something goes wrong, it keeps getting hit by all the work. If I prefer to hurt it ... "(Student C).

The joy expressed by students is an expression based on familiarity with the robotics media used. Because students with Assimilating learning styles tend to explore a lot of models and think about them as a whole [4]. Students tend to like assembly activities because students need time to explore to find the facilities needed.

Assignments given to robots are familiar to students so they can be proactive in their lessons [29]. Active attitudes can be demonstrated by students during the STEM learning process with Lego Mindstorm, who have familiar concepts with their childhood games. Furthermore, the importance of achieving familiar feelings or familiarity with students in learning can help them to capture a broader imagination [30].

4.4 Developing Students Imagination

To create or develop a variety of creative concepts that are feasible, unique, and new, a good imagination of students

is needed [31]. Imagination as one of the attainments of student behavior patterns in the learning process is needed because it influences student learning outcomes directly or indirectly. Creativity will significantly help students to be able to determine life choices and overcome various problems faced in the future [32].

Based on the results of the study, students' imagination was found as one of the attainments of student behavior patterns during the STEM learning process using Lego Mindstorm robotics media. All participants have their ways of imagining, but still in a similar context. First, Converging and Diverging students have thoughts about the final results of the robotics model created and secondly, how the development they will undertake on existing models becomes the focus of Accommodating and Assimilating students.

Each student with the characteristics of converging turned out to have a similar concept of thought. These four students tend to imagine the final results of the robot model that will be made while the assembly process is still ongoing. One of them is student A who has his own view of the form of the robot he is assembling,

"I think for a model like a tractor. The problem is that the initial shape has a claw in the front part ... "(Student A).

Students rely on the visualization shown by the first part of the model and compare it with what is in the real world such as tractor work tools. This is in line with Kolb's theory that in one of the indicators Converging is Abstract Conceptualization, where students logically compare things they see during the learning process with real situations of daily life [33].

Meanwhile, Student E with diverging characteristics imagine robots since before the practice of assembling with Lego Mindstorm components.

"When I saw from the picture, I thought that the robot that was made had legs and not a vehicle like that ..." (Student E).

Based on pictures showing the final results of the model, students rely on their exploration abilities. This proves that the Diverging learning style tends to require time to observe what things are nearby before doing something [12]. Students need a comparison to shape their imagination.

On the other hand, Assimilating and Accommodating students have a view on the development of the assembled robot model. Previously said by C students with Assimilating characteristics when asked about the development of the robot model they would do,

"If the claws can be developed. It doesn't just fly, and it just pops like sand ... "(Student C).

Students connect their imaginations with objects that exist in real life, specifically to the function of development if done. This indicates the similarity of Assimilating students and Converging students. Because learning styles Assimilating and Converging have indicators of Abstract Conceptualization [4].

As with Accommodating students, they have different expressions about their imagination. In accordance with the character of the learning style, Accommodating students are more willing to be creative in taking risks to see the results of the work [12]. Following is the opinion of Student D with Accommodating characteristics which have an imagination of the series of robot models they make,

"If I can develop it, I will make it like a spider being given a claw and then the box that makes things on its body ..." (Student D).

The imagination imagined by student D is based on a similar concept to the initial model that was previously created. This shows that Accommodation students tend to be more active in expressing their ideas and ideas during the STEM learning process using Lego Mindstorm robotics media.

4.5 Developing Logical Thinking Ability in Facing Learning Situations

Lego Mindstorm Robotics requires students to be able to think logically because they carry out a series of instructions to be executed [34]. With logical thinking skills, students are able to improve their ability to innovate creatively in a fun and engaging learning environment [35]. So logical thinking becomes one of the achievements of student learning processes in learning STEM with Lego Mindstorm robotics media. Like for example, what was stated by student B who had the characteristics of converging when asked to express about a solution when faced with problems in learning using Lego Mindstorm,

"There is a picture of a robot that has already been made at the bottom, well, it is investigated again, what parts are we lacking to find the missing components ..." (Student B).

In accordance with one of the indicators of Converging in the form of Abstract Conceptualization where students will analyze the situation at hand and can then generalize their findings [12]. Student B logically pays attention to the picture of a series of robot models that have been completed at the end of the module, with the hope that he can find deficiencies in the model in the picture with the robot he is making. Student analysis compares models that can be used as examples to find solutions to problems in a more practical way.

On the other hand, Accommodating students have a way of thinking logically from a different perspective. Student D with Accommodation characteristics expressed their opinions on STEM learning using Lego Mindstorm robotics media,

"The model is attractive that made me imagine how it works. For example, there is an object in front of the sensor below; he first reads if it is right then it will be pinched but if it is plain wrong just go straight ... "(Student D).

Students describe the concept of robotics logically according to the understanding they receive after the activity is carried out. This is relevant to Kolb's theory which states that students with Accommodating learning styles have the ability to learn from "direct" experience [27]. Henceforth students are able to share direct experience relying on their logical thinking skills in simple explanations.

While Students C with Assimilating learning styles show different behaviors. Like for example when student C is asked to express his opinion about the robot model used in learning,

"It's logical, right? It can also be used to transport garbage. But take it one by one, it can't be much (truck claw model). So if you can develop the claws. It doesn't just fly, and it just pops like sand ... "(Student C).

This is able to stimulate the abilities of those involved in logical thinking because students make modifications according to real-life [36]. The modification referred to in this case is related to the imagination of students based on their logical thinking.

Students in diverging learning styles, on the contrary, show less behavior that expresses logical thinking. This is relevant to Kolb's theory that diverging students will prefer exploration activities to rely on their experiences and think about it more deeply [12] compared with having to think rationally and logically to solve a problem.

5 Conclusion

Taking steps towards evaluating human cognition from a particular lense perspective is challenging. First, there is a lack of consensus in the field in terms of what may come up as the potential findings. This is critically important as the efficacy in STEM is a valuable skill for a future relevant career. The paper contributes to theory by adopting Kolb's Learning Style instrument to map students' learning styles pattern and further corroborating with students learning experience in a robotics STEM environment. The research findings answer the research question by elaborating on how individuals with diverse learning styles constructed

their cognitive aspects while psychometrically involved in STEM robotics activities. Another notion revealed in the research is that prior experience contributes to students' knowledge generation processes and logical thinking abilities. While the Kolb Learning Style and its instrument are considered classic in hands-on literature, the use of educational robotics to elaborate students' learning style is novel in the literature that may be applied to many other STEM learning areas.

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