STEM-based Learning Blended with Inquiry-based Learning for Medical Students through Forensic STEM Activities

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***Abstract* - In many countries STEM (Science, Technology, Engineering and Mathematics) education plays a critical role in teaching and learning. As one of the active learning methods STEM-based learning is considered a choice of science learning approach in the 21st century. In combination with inquiry-based learning, it would potentially synergize learning to become more effective. Among a wide variety of STEM-based learning applications such as food, drug, and health environment, forensic STEM is one of the interesting themes for teaching at the college level especially to medical students. The main goal is to use STEM-based and inquiry-based learning to make students learn about data analysis and interpretation, which is essential to machine learning in the context of Forensics STEM. In our research reported here, it was found that students have the opportunity to open their worldview with the learning that is not mainly focused on lectures or content memorization. It provides an opportunity for students to explore how to learn with the new approach differs from what they typically experienced especially as a 1st and 2nd-year medical students. This Forensic STEM provides a learning platform that enables students to learn the multidiscipline involved via the context of forensics.**

Keywords - STEM-based learning, Forensic STEM, Inquiry-based learning, Machine learning, Medical students

I. INTRODUCTION

STEM education plays a very important role in teaching and learning. As predicted by many experts, the jobs of tomorrow will require at least some competency in STEM fields—Science, Technology, Engineering, and Mathematics [1]. It is also believed that from now on there will be such hard-pressed to find a job in the coming decades without a robot or AI or Machine learning competency [2]. One of the fastest-growing areas is human-robot interaction and the development of collaborative robots, known as co-bots. It is interesting how human beings will respond to this change to avoid being replaced by a robot or AI.

As a medical doctor, like other careers, they also need to be able to respond to these changes because now there is no career immune or secured. No industry will be immune as well. Therefore, how exactly higher education like college or university should play a role or prepare for this dramatic, disruptive change is yet to be seen. One thing for sure that higher education needs to become is to make themselves to be more adaptive and innovative if they still want to be the foundation of the learning society.

In this work, we have focused on medical students who are considered to be one of the top choice and most respected careers in society, especially in Asian countries. We aimed to make students learn of machine learning and forensic STEM [3]. via STEM-based integration learning. We also believe that STEM+HA (where H is Humanity and A is Art) would enhance the effectiveness of STEM education. Our STEM team has a good opportunity to arrange the workshop for medical students from Kunming Medical University, China during November 2018. We designed the workshop as the Forensic STEM module for the student to learn STEM, forensics, technology-enhanced learning, and machine learning. And in this paper, we will present one activity, namely "Forensic STEM: Who is the killer?". We used some procedures from Forensics with Vernier's lesson developed by Vernier Software & Technology Company (https://www.vernier.com/). This book is designed for teachers at the high school level who wish to introduce their students to forensics using engagement and realistic laboratory activities with Vernier Probeware™. We modified the lesson to make it more fun, hands-on, and flexible. By flexible, it means that students could analyze data using the conventionally low technology tool like graph paper or use the high technology application on mobile phone platforms. Hence, it could consider to be the lesson that can learn anywhere and anytime both unplugged or plugged. The main learning outcomes for this activity is for the learner to be able to demonstrate as follows: 1) learn to how to learn via STEM-based learning, 2) analyze data to critically solve the problem, and 3) explain in a pedagogical way what machine learning is.

We used the inquiry-based learning (IBL) approach, a form of active learning, for this activity. It can also be viewed as constructivist learning [4]. With this designed activity we can provide the medical students the learning opportunity to exercise their generic and specific skills. In other words, soft and hard- skills have become more and more important than learning by focusing on knowledge only.

We believe that this could also open up the breadth and depth way of learning. It can also provide the learner with career guidelines for the future of their careers like MD-PhD. It is more meaningful learning to rather set mind only on to become a knowledgeable doctor, but also an inquiry mind kind of the doctor. Indeed, it turns out to be a good opportunity for us to learn so many things from these medical students as well. Not only about the profession, it is also about learning the culture, perception, and belief.

II. LITERATURE REVIEW

Inquiry-based learning (IBL) can be considered as an effective pedagogical approach for STEM education, especially for 21st Century Learners. Research findings have shown that an inquiry-based approach is beneficial to students and that even young children can learn through inquiry processes [5]. The findings from several research studies such as Renner, Abraham, and Birnie [6], and Abraham and Renner [7] suggests that, in comparison with traditional pedagogy, the learning cycle can result in better retention of science concepts, higher achievement in science, superior process skills, improved attitudes toward science and science learning, and improved reasoning abilities.

Constructivist learning is a process to combine pre-existing knowledge with new knowledge in the creation and development of conceptual [4]. This is the theory on which several instructional models have been based. Each Instructional model tries to describe a learning process as steps to form the integration of pre-conditioning for motivation and lead to learning outcomes in education. The development of instructional models can be traced back to the early stage of philosophy and takes deep root in science education [8 -12].

With such a consequence, several models for instructional models have been proposed and active in recent years in academic circles.

These include, for example, Learning Cycle Model (also known as 3E), 4E, 5E, and 7E. Learning Cycle Model describes the process as 3 steps of Exploring, Explaining, and Elaborating, known as 3E in short. 4E model adds one more step before Exploring with pre-conditioning of Engaging and changes Elaborating with Evaluating to form, or Engage-Explore-Explain-Evaluate. However, 5E model inserts Evaluating back into the step before Evaluating and forms an Engage-Explore-Explain-Elaborate-Evaluate model [13]. 7E model requires higher steps to increase high advancement in learning to make students Engage, Explore, Explain, Elicit, Elaborate, Evaluate, and Extend [14].

Among the models described above, 5E has been widely adopted in the science community [4, 15].

III. METHODOLOGY

Here we specifically use The 5E Inquiry-Based Instructional Model [16]. The 5E Inquiry-Based Instructional Model can be used to design science lessons, that is based upon cognitive psychology, constructivist-learning theory, and best practices in science teaching. It consists of cognitive stages of learning that comprise engage, explore, explain, elaborate, and evaluate as shown in the diagram Figure 1. These activities are designed in “the theme of detective” to make the story more interesting.

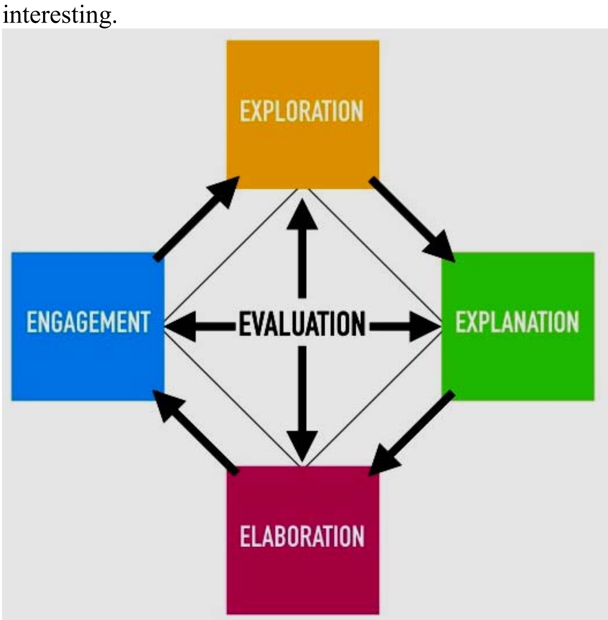

Fig. 1. The 5E Inquiry-Based Instruction Model.

E1: Engagement

In this first phase of the cycle, we aim to assess students’ prior knowledge and introduce them the Forensic STEM, Machine learning and AI. For this student-centered phase, we tried to motivate students to want to learn more about the topic. We also let a student do brainstorm with our opening questions and ask them.

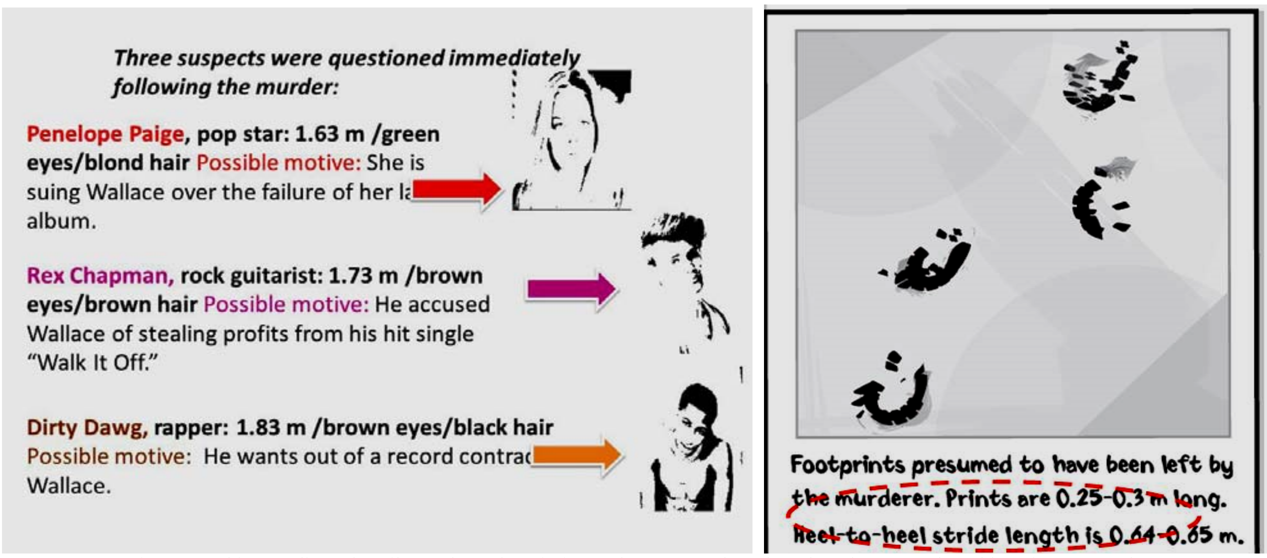

Fig. 2. Teaching media to describe students the mission and engage students based on the STEM-based learning approach.

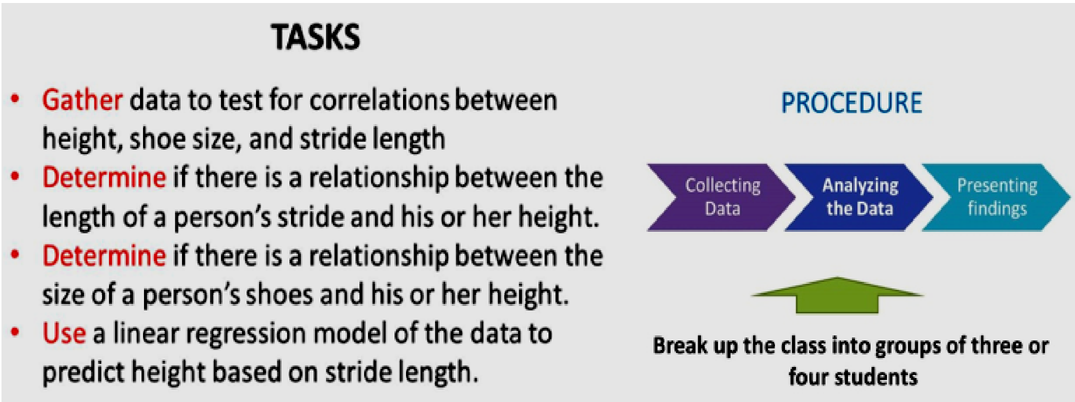

Fig. 3. The sample teaching media for the exploration phase.

We introduce some of the past popular movies such as crime scene investigation (CSI), Sherlock Holmes, The Pink Panther, Ace Ventura: Pet Detective, and Detective Conan, etc. It is to engage the learner to make sure that they feel happy to learn and want to learn. The movie-like CSI does portray the exciting world of crime scene investigation to the public. Hence with the popularity of CSI shows on television, forensic science is a great way to spur kids to get engaged in STEM. Then we make a connection with the movie story with the everyday life experience. We show some NEWS about the homicide to the learner to introduce Forensic Science. With the breakthrough of the advance technology and the digital age, technology disruption is one of the underline reasons that forces much industry to change and respond with industry 4.0 including health and medical areas. Therefore, Forensic engineering [17] has emerged. Hence here we design the integrated study using a STEM-based learning approach so that we toss the word FORENSIC STEM. Worldwide some learning activities want to make students learn using the context of forensics via STEM such as STEM students explore forensic science at the National Forensic Science Technology Center (NFSTC). Below is the situation we asked students to perform an activity.

E2: Exploration

This student-centered phase is for incorporating active exploration. We encouraged students o apply process skills, such as observing, questioning, investigating, testing predictions, hypothesizing, and communicating, among teammates. We use the linear regression approach as a means to get an estimation for the possible murder. Here The teacher's role is one of facilitator or consultant. Also, students are encouraged to work in a cooperative learning environment without direct instruction from the teacher. This phase is also unique because the students are given "hands-on" experience before any formal explanation of terms, definitions, or concepts are discussed or explained by the teacher. Here the students:

1. Are provided with the knowledge handout. The case situation including the crime scene, motive and description of the suspects.
2. Are provided with the graph paper
3. The blank paper for discussion, interpretation, and conclusion.

E3: Explanation

This a "minds-on" phase following the exploration phase, is more teacher-directed and guided by the students' prior experience during the exploration phase. We focus on making students be able to describe their understanding and pose questions about the concepts they have been exploring. Usually, new questions will likely be generated, and another question comes after the other. The explanation phase is an essential, minds-on part of the 5E lesson. Here we let the students discuss with their team about how to understand data and information on the case study. This phase tends to provide an opportunity for students the creatively a critically express their explanations and ideas. We try to facilitate them to ask questions to their friends to describe and discuss their exploration learning experiences. After that, we introduce scientific and technical information such as how to fit curve, what the linear regression means, how to evaluate and determine what should be the GO TO best fit, etc.

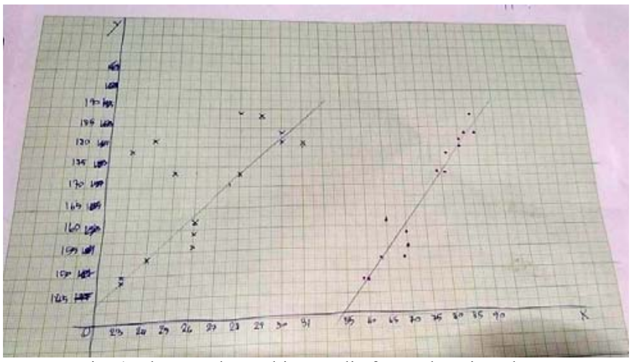

Fig. 4. The sample teaching media for explanation phase.

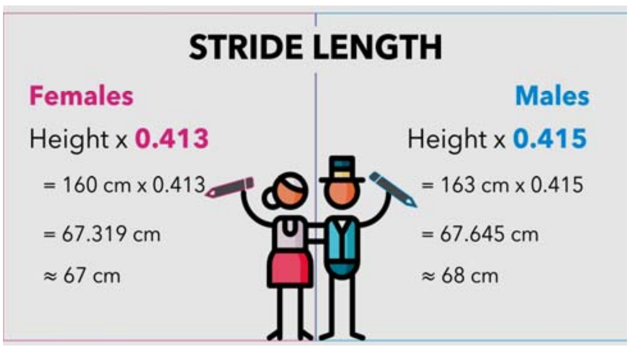

Fig. 5The sample of the teaching media for the elaboration phase.

We also tried to explain misconceptions that may have emerged in previous phases. At the end of this phase, students should then be able to clearly explain the important concepts to the teacher and their peers. Figure 4. below is the sample of the graph of the data and data fitting to show the student that this is one good way to understand and explain the computational data. This is more like the scratch of the data which we usually use for the student to ask, comment or suggest about what and how to improve this graph.

E4: Elaboration

In this phase of the learning cycle, we encouraged students to apply their new understanding of concepts, while reinforcing new skills. The goal of this phase is to help develop a deeper and broader understanding of the concepts. We expect the students to be able to may conduct additional investigations, develop products, share information and ideas, or apply their knowledge and skills to other disciplines. This is a great opportunity to integrate science with other content areas. Elaboration activities may be integrated with technology-enhanced learning. It is one of the central goals of STEM-based learning to make students connected their knowledge with another context. Students must be aware of trying to ask themselves why do they need to learn this and that or how they can apply their knowledge or skills for daily life problem-solving.

In Figure 5, we challenge the student with the formula to estimate the stride length knowing the height. From the exploration phase, they will learn the relationship between stride length and height through data analysis. Hence students are encouraged to discuss with their peer to find what the above relation come from.

E5: Evaluation

Interestingly, assessment in an inquiry-based setting is very different from that in traditional science lessons. Usually, we use an assessment of learning (summative assessment) and the assessment for learning (formative assessment). Feedback is the key ingredient of the later. During inquiry-based learning, assessment should be viewed as an ongoing process, with teachers making observations of their students as they apply new concepts and skills and looking for evidence that the students have changed or modified their thinking. Students may also have the opportunity to conduct self-assessment or peer-assessment. In this activity, we encourage the student to evaluate all on-process work including data collecting procedure, data analysis, interpretation, and conclusion. Still, the evaluation may also include a summative experience such as a quiz, exam, or writing assignment. It should be emphasized that the key factor that makes the assessment effective is content validity, reliability, fairness, student engagement and motivation, consequential relevance.

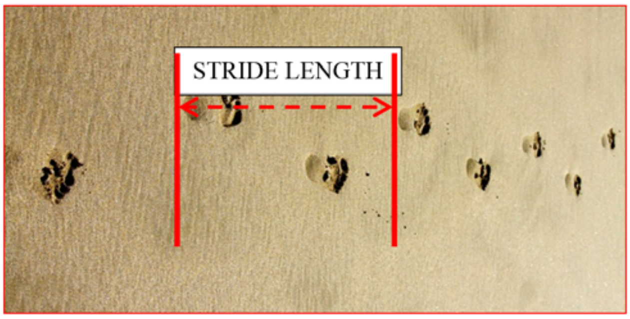

Fig. 6. The sample of the teaching media for the elaboration phase.

Part I: Collecting Data [18]

1. Use the tape measure to measure each person's height without shoes to the nearest 0.1 m, and record it in the Evidence Record next to the person's name.

2. Have each person remove his or her right shoe. Turn the shoe over and use a ruler to measure the distance from the tip of the toe to the end of the heel. Record the length of the person's shoe in the Evidence Record Table (See Table I).

3. Mark a starting line with chalk or tape. Have each person stand with the backs of his or her heels at the edge of the starting line. Starting at this point, each person should take 10 normal-length walking steps in a straight line (see the diagram below). After the 10th step, the person should stop and bring his or her heels together. Mark the final position of the back of the person's heels and measure the distance to the nearest 0.1 m between that mark and the edge of the starting line. Calculate the average stride length by dividing this distance by 10. Record each person's average stride length to the nearest 0.1 m in the Evidence Record.

4. When all the data are collected, compile a complete record for all individuals on a master Evidence Record.

Part II: Analyzing the Data

Next, you will determine the equation for the straight line that fits your data the best. It is important to have an equation that describes the relationship between height and stride length. If you have an equation, you can predict the height of any person based on the length of the person's stride.

$$\text{Stride length} = (m)(\text{height}) + b,$$

where the m and b are constants. It is possible to calculate the equation by hand, but it can take a long time. However, one can use an application or program concerning the linear regression analysis tool to quickly calculate the m and b for your data.

5. Create a graph of average stride length vs. student height.

6. Perform a linear regression of the average stride length vs. student height data.

7. Repeat Steps 3–4 to determine whether there is a relationship between student height and shoe length. Graph shoe length on the y-axis and student height on the x-axis.

8. Answer the questions in the Case Analysis, using your results.

TABLE I. THE EVIDENCE RECORD TABLE

Student Name	Height (m)	Shoe Length (m)	Stride Length (m)

Equation describing the relationship between stride length and height: ______________

Correlation value for stride length vs. height length: _______

Equation describing the relationship between shoe size and height: _____________

Correlation value for shoe size vs. height: _______________

IV. RESULTS AND DISCUSSION

In this activity, we did emphasize to students about the most important purpose of the study, namely to find the relationship between the height vs. stride length and the height and the shoe size. Then we use that relationship to figure out the corresponding height provided by the evidence at the crime scene. So, after having all data in hand, students have to find a way to analyze the data using the available tools bot "Plugged" and "Unplugged".

For the sake of simplicity and we want to especially focus on the data analyzing as follows.

Fig. 7. Shows the hands-on data collection.

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TABLE II. DATA OF STUDENTS' HEIGHT, SHOE LENGTH, AND STRIDE LENGTH
(*Sample Data*)

Student Name	Height (m)	Shoe Length (m)	Stride Length (m)
Student 1	1.47	0.23	0.58
Student 2	1.59	0.26	0.70
Student 3	1.87	0.28	0.88
Student 4	1.77	0.23	0.82
Student 5	1.80	0.31	0.85
Student 6	1.61	0.26	0.65
Student 7	1.74	0.28	0.78
Student 8	1.89	0.29	0.89
Student 9	1.82	0.24	0.85
Student 10	1.84	0.30	0.87
Student 11	1.49	0.23	0.60
Student 12	1.53	0.24	0.68
Student 13	1.56	0.26	0.70
Student 14	1.74	0.25	0.81
Student 15	1.81	0.30	0.85

We asked the students to plot graph Height vs. Shoe Length and Height vs. Stride Length and used it to figure out the murder. Here we asked students to plot a graph using Graph paper (linear plane) first (Unplugged) and the asked them to use either application software downloads such as Curve Fit or Excel Microsoft program (Plugged). Most students found that it was more convenient to use the "Plugged" version mainly because it can provide the fits called linear regression as well as its associated correlation value R2 . And with the reliable curve fit they can use it as the standard curve to figure out or predict the height of any person based on the length of the person stride. Of course they can also use the determined linear equation to predict the height value as well. It can also be done by hand. It should be remarked that this was done assuming the relation between height and stride length is linear. Below is the sample of the fitted data by excel program.

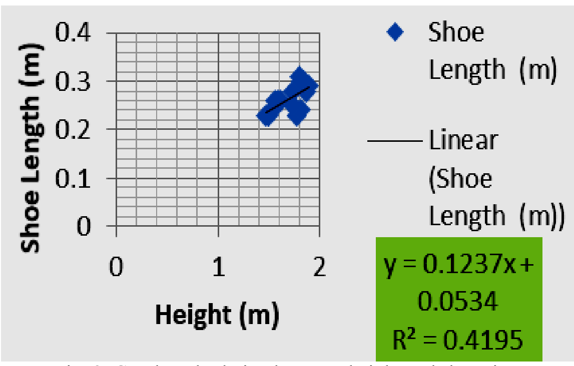

Fig. 8. Graph and relation between height and shoe size.

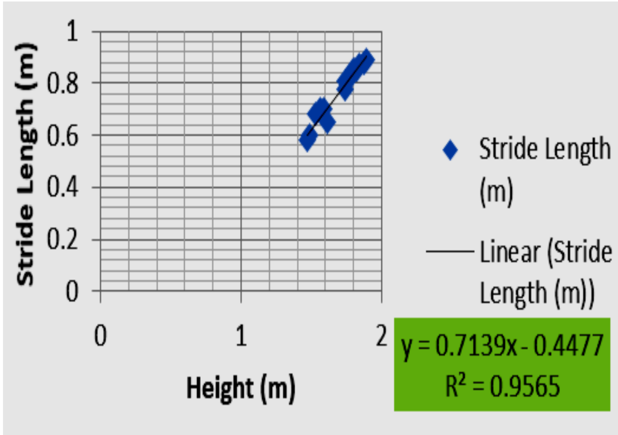

Fig. 9. Graph and relation between height and stride length.

At this point, students would find that there are two possible relationships namely Height vs. Shoe size and Height vs. Stride Length. And they must critically think and analyze which one is the better fit for this situation. Some students could figure out and some are not. The key is the correlation value which is a statistical measure that calculates the strength of the relationship between the relative movements of two variables. If the values at or close to zero imply weak or no relationship, meaning it is possible that the students may enter incorrect data or that their measurements were inaccurate. If the values close to 1 implied a significant relationship. In this case, the relationship between Height and Stride Length is more correlated (0.95 is acceptable). In other words, it would be more reasonable to infer a person's height from his or her stride length. Hence it would be more reliable and more reasonable to use the graph in Fig. 2 to be a standard curve to predict the Height. Consequently, from the footprint presumed to have been left by the murderer, 0.25-0,30 m long and Heel-to-Heel stride length is 0.64-0.65 m. We use the relationship Height vs. Stride Length to calculate the height given the stride length equals 0.65. We then found that the height is around 1.54 m. Therefore, based on the given sample data, Penelope Paige most likely to be the murder or more precisely was the one of left the footprint. To elaborate more, we asked the students to discuss the possible reasons for the incorrect prediction of height. Their response was: maybe the person was running.

To students, we also emphasized the fact that fitting data creating a graph is one of the ways to make the machine learn: machine learning. And this is the foundation of the Artificial of AI which is one of the key tools of today and future. We want to mention that this Forensic STEM activity, especially for these Chinese medical students, is meant to them more than just the knowledge. It does affect the way they feel about learning as well. In this activity, students had the opportunity to explore how to learn with the new approach different from what they typically experienced especially as a 1st and 2nd year as medical students.

Here are some of their feedbacks.

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Student 1: I think I will use the knowledge and skills into the way of studying and thinking in my life especially the STEM.

Student 2: I'm very enjoying the way of teaching. I have more time to think deeply before class.

Student 3: The way of teaching really impresses me. It's perfect.

Student 4: In STEM lesson is interesting and all of the labs are what I dream.

Student 5: I learned a lot, and I will use the STEM knowledge and skills to my work.

Student 6: The courses are so interesting. I never take a class like this before.

It was found that students have the opportunity to open their worldview with the learning that not mainly focus on lecture-based or content memorization.

V. CONCLUDING REMARKS

The Forensic STEM activity was conducted to visiting medical students from China. The main goal is to use STEM-based and inquiry-based learning to make students learn about data analysis which has implications for machine learning and AI through the context of Forensics. It was found that students have the opportunity to open their worldview with the learning that not mainly focus on lecture-based or content memorization. It provides an opportunity for students to explore how to learn with the new approach different from what they typically experienced especially as a 1st and 2nd year as medical students. This Forensic STEM is decided to make students learn the multidiscipline via the context with the forensic.

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REFERENCES

[1] J. Hom. Elaine, "What is STEM Education".[Online]. Avaliable:https://www.livescience.com/43296-what-is-stem-education.html [Accessed Feb. 11, 2014].

[2] Lake, B., Ullman, T., Tenenbaum, J., & Gershman, S. (2017). Building machines that learn and think like people. Behavioral and Brain Sciences, 40, E253. DOI:10.1017/S0140525X16001837.

[3] http://stem-works.com/subjects/3-forensics

[4] Bybee, R. W., Taylor, J. A., Gardner, A., van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. "The BSCS 5E instructional model: Origins and effectiveness"., The Office of the Science Education National Institutes of Health

[5] Etheredge, S., & Rudnitsky, A. (2003). Introducing students to scientific inquiry: How do we know what we know? New York: Pearson Education.

[6] Renner, J. W., Abraham, M. R., & Birnie, H. H. "Secondary school students' beliefs about the physics laboratory". Science Education, vol.69, no.5, pp. 649-663, 1985.

[7] Abraham, M. R., & Renner, J. W. "The sequence of learning cycle activities in high school chemistry". Journal of Research in Science Teaching, vol.23, no.2, pp.121-143, 1986.

[8] Rutherford, F. J., & Alhgren, A. "Project 2061: Science for all Americans"., Oxford University Press,1990.

[9] Abdi, A. "The Effect of Inquiry-Based Learning Method on Students' Academic Achievement in Science Course". Universal Journal of Educational Research, vol. 2, no.1, pp. 37-41, 2014.

[10] Driver, R., "Pupils' alternative frameworks in science"., European Journal of Science Education, vol. 3, no. 1, pp. 93-101, 1981.

[11] Hofstein, A., & Mamlok-Naaman, R. "The Laboratory in Science Education: The State of the Art". Chemistry Education Research and Practice, vol. 8, no. 2, pp. 105-107, 2007.

[12] Wilson, C. D., Taylor, J. A., Kowalski, S. M., & Carlson, J. "The relative effects and equity of inquiry - based and commonplace science teaching on students' knowledge, reasoning, and argumentation" . Journal of Research in Science Teaching, vol. 47, no. 3, pp. 276-301, 2010.

[13] Duran, L. B. & Duran, E. "The 5E Instructional Model: A Learning Cycle Approach for Inquiry-Based Science Teaching". Science Education Review, vol. 3 no. 2, pp. 49-58, 2004.

[14] Eisenkraft, A. "Expanding the 5E Model", Science Teacher, vol. 70, no. 6 pp. 56-59, 2003

[15] Edelson, D., Gordin D., & Pea, R., "Addressing the Challenges of Inquiry-Based Learning Through Technology and Curriculum Design". Journal of the Learning Sciences, vol. 8, pp. 391-450, 2011.

[16] Bybee, R., & Landes, N. M. "Science for life and living: An elementary school science program from Biological Sciences Improvement Study (BSCS)". The American Biology Teacher, vol. 52, no. 2, pp. 92-98, 1990.

[17] https://en.wikipedia.org/wiki/Forensic_engineering

[18] https://www.vernier.com/experiments/fwv/1/tracks_of_a_killer/