International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 08, 2020
ISSN: 1475-7192

Enhancing the Learning Outcomes of Automotive Electrical Wiring Diagram through Android Simulation – A Conceptual Design for Automotive Vocational School

[1]Ibnu Mubarak, [2]*Warju Warju, [3]Fajar Danur Isnantyo, [4]Muhammad Nurtanto, [5]Reza A. Rahman, and [6]Suyitno Suyitno

***Abstract*--**The implementation of technology in the learning process must be implemented as a real effort to improve the quality of education in the industrial era 4.0. Technology can be utilized to achieve adequate learning outcomes that conform to the student's characteristics at present. This article discusses the application of technology in the learning process for an automotive vocational school. The designed application is a game-based challenge which able to installed either in a mobile telephone or computer for learning the automotive electrical wiring diagram. As technology develops in vehicles that utilize a lot of electrical and computer systems, thus the outcomes in automotive vocational schools must be adjusted to real conditions in the field. The automotive electrical system is an essential lesson for automotive vocational education, and it requires a depth understanding of the student, which trains the student's high order thinking skills. In order to maximize the learning process, the authors and teams design a game-based application on a mobile phone for the automotive electrical wiring diagram course. The application was developed according to the current student's characteristics which familiar with the mobile phone. The goals of the concept are to improve the learning process and ease of use for teachers and students during the class activities. The application is designed based on the automotive electrical wiring standard. After the initial test, the authors and teams found this concept can attract students' interest in learning the automotive electrical system even though the topic is considered as difficult level (High Order Thinking) and gives positive results in achieving the target of learning outcomes.

***Keywords*—**Automotive electrical wiring diagram, Vocational School, Generation Z, Learning Media

[1]Department Pendidikan Teknik Mesin, Universitas Pendidikan Indonesia, Bandung, Indonesia.
[2]Department of Mechanical Engineering, Universitas Negeri Surabaya, Surabaya, Indonesia, *Email: warju@unesa.ac.id
[3]Department of Civil Engineering Education, Universitas Sebelas Maret, Surakarta, Indonesia.
[4]Department of Mechanical Engineering Education, Universitas Sultan Ageng Tirtayasa, Banten, Indonesia
[5]Department of Researcher and Professional Certification Agency in Indonesian Automotive Technicians (LSP-TOP), Indonesia
[6]Department of Automotive Engineering Education, Universitas Muhammadiyah Purworejo, Purworejo, Indonesia

Received: 27 Mar 2020 | Revised: 20 Apr 2020 | Accepted: 05 May 2020

I INTRODUCTION

It is undeniable that the presence of the 4.0 Industrial Revolution must be followed by the revolution in the education system. This condition is important to consider because there is a large gap between what industry needs for the workforce and the fulfillment of the workforce from schools, particularly from vocational schools. The phenomenon caused a serious problem in society that the increase in the unemployment rate, which farther may lead to a chain effect both in the economy and social aspects. The adjustment should focus on vocational schools as this school is designed to occupy the human resources for the industry.

In Indonesia, the high rate of unemployment is mostly coming from vocational school graduates. There are many factors why the high rate of unemployment can happen, such as the un-proportionate between work vacancies and workforces, uneven distribution of employment, mismatches between vocational programs and needs in industry and also the lack of competence from vocational school graduates which does not meet the industries expectation. The government is trying laboriously to solve this problem, especially by focusing on the link and match program [1], [2].

One factor that is quite influential is the mismatch between the implementation of the curriculum being taught and the needs of the industry. The author takes focus on the vocational school (*Bahasa: Sekolah Menengah Kejuruan*) for automotive major (*Bahasa: Teknik Kendaraan Ringan Otomotif*), the mismatch between competencies of major automotive graduates with standards expected by the industry can be seen clearly from various aspects. For instance, the materials and learning competencies used still refer to the old vehicles (under 1995), which is different from the systems and utilities compare to the current vehicles. It is one of the biggest factors why graduates' competencies become less appropriate and could not meet the industry's standards.

The development in automotive technology must be accompanied by improvement and adjustments for the learning outcomes in the vocational school [3], [4]. On the other hand, it needs to be also understood for the characteristics of students today, which are considered as what it called as generation Z (born 1999-2015). The typical generation Z characteristic they are familiar with "screen" (mobile phone, computers, and other devices). Generation Z has its characteristics that are in sharp contrast to the previous generation (generation Y and below), so there is a need to promote a special strategy to attract their interest for learning, adjusting the target of learning competence and habituation to critical thinking (High Order Thinking skills) [5]–[7].

The current jobs in automotive services demand higher analytical skills because modern vehicles use electronic control systems. In other conditions, working in automotive services also involve a lot of "screen" activities such as computers, diagnostic tools, and system scanners. The ability to read the vehicle's electronic system and also analyze the vehicle's electrical system is considered as an important skill to be mastered by automotive vocational graduates at present. However, the challenge is the learning outcomes about electricity are a topic that generally considered difficult for students and the teachers' educator because it requires a strong basic electrical understanding and high analytical skills for troubleshooting [8]–[13].

Recognizing these problems and challenges and the author's experience as an automotive teacher, especially for the automotive electrical course, the author senses the urgency to create a new media for teaching the

Received: 27 Mar 2020 | Revised: 20 Apr 2020 | Accepted: 05 May 2020

automotive electrical system that may attract student's interest in learning this topic and maximizing the achievement of learning goals. The author considers that the new media can be used as a system simulation that provides a real reading, so when students use it, they can know the true or wrong conditions. Another important aspect is the characteristics of generation Z, the new media must be made as attractive as possible, provide challenges, and also the existence of "levels" that are expected to be able to attract interest among students to compete so they can concentrate further in learning to understand the material in the media [14]–[17].

The author and team tried to develop a game-based on android device (for mobile phone) for the automotive electrical wiring diagram topic. The game is designed as a simulation for wiring the circuit in body electrical system. The designed game is made by keeping the electrical standards in automotive, having an attractive appearance, friendly user interface both for teachers and students and also does not require high specification for the device (lite version) [18]. The purpose of this game trial is to offer an idea to involve the technology in the learning process so that learning process can be done anywhere (does not limited by place and time), the learning process becomes more effective both for teachers and students. Farther, it is also expected through this game may help to spread an equitable and useful information across the country.

II LITERATUR REVIEW

1) The Development in Automotive Electrical System

This section only briefly discusses the development of existing technology in automotive and its relation to the expectations of automotive vocational graduates. The modern vehicle involves many electrical systems, the engine control system, braking systems, steering systems, accessories systems, so forth, have developed largely. The common examples for the modern vehicle electrical systems are Electronic Fuel Injection (EFI), Anti-lock Brake System (ABS), Electronic Power Steering (EPS), Auto Levelling Light Beam, and so on.

The increase in the automotive electrical system demands the technicians to be mastered the electrical system and be able to carry out diagnosis, analysis and repair (troubleshooting) for the systems. Regular maintenance activities remain a compulsory competency and this activity requires additional tools such as the Diagnostic Tool and the System Scanner. The tool is used to check whether the system is working normally or not [19]–[22]. With the increasingly sophisticated system, a skilled and competent technician is needed to carry out maintenance and repair of the vehicle. Moreover, technicians are required to have sufficient analytical skills in solving problems that exist in vehicles. It is an important requirement for automotive vocational graduates at present to be able to do these jobs.

2) Generation Z

Generation Z or those born in 1999-2015 (some reports call it from 1996 to present) is a developing generation where the dynamics of technology are quite advanced. The characters tend to socialize and express themselves, high mobility, global-minded, communicate digitally and prefer visual things. Some studies state that 41% of the generation Z spend more than 3 hours in front of the screen and check social media more than 100 times per day. They have a high level of familiarity with digital devices such as smartphones and portable computers (laptops). The adjustment of learning media needs to be taken seriously by education practitioners so that learning targets

can still be achieved to the maximum extent possible by considering their character. Other conditions also require that the development of media created or modified must be able to attract their interests so that the learning process becomes more interesting than usual, and the possibility of achieving learning objectives increased [23]–[25].

3) Learning Media

The learning media are all things that can be used to deliver messages or information during the learning process and able to stimulate the attention and interest of students for learning [13], [26]–[28]. The learning media has an important role, especially to overcome the boundaries of the classroom, able to generate new desires and interests and be able to diffuse the basic concepts correctly and concretely [29], [30].

The role of the media is so crucial that it needs to be considered in the use of media related to the level of difficulty of the topics being taught, the students and the diversity of characteristics of students. Following Edgar Dale's experience cone that 70% of the experience can be gained through active activities, such as conducting a simulation. The selection of appropriate learning media will ultimately provide an effective learning experience, and learning objectives can be achieved as ideally as possible [31].

4) Automotive Electrical Wiring Diagram (EWD)

This term refers to the electrical diagram used to represent the electrical system that exists in a vehicle. This diagram contains standard symbols and also the way of reading that has been arranged in such a way as to facilitate the process of circuit analysis. EWD is very important to be mastered for vehicle technicians because the function of the electrical system is very vital in vehicles, especially for modern vehicles, which are generally based on electronic controls.

The challenge in teaching and learning about EWD is the difficulty of simulating the course of an electric current. It is a major obstacle for students in understanding how the electric current goes in a circuit. This obstacle can be overcome by using interactive media that can provide simulations of how the electric current runs in a circuit and also the arrangements between the cable and electrical components [32]–[34].

III DESIGN AND CONCEPT

The Electrical Wiring Diagram (EWD) learning media simulator is designed as a "puzzle game" in the form of a EWD electrical circuit simulation. This circuit simulation will take the form of a flow puzzle game. This concept is different from the concept of game flow as in general; in this simulation, the player simply touches the first and second objects. If the two components are connected in pairs, the score will increase and then the components will be connected by lines (as a cable representation). If wrong, the score will decrease.

This simulation involves several basic electrical symbols in the automotive standard. The components used are relays, switches, fuses, light bulbs, motors, horns and batteries. All components are represented as standard symbols. The combination switches represent the logic table. The main purpose of this simulation is to practice the ability to read wiring diagrams and also the electric current flow, which represented in the form of cable colors (dark green for negative, red for positive). The game is divided into three leveling stages, with the contents and shapes of each stage modeled after a series of exercises from the material taught by the teacher. The next stage will be locked until the player completes the previous stage.

1) Stage 1- EWD Sketch (easy)

The simulation on the first stage requires the player to connect each component according to the wiring diagram sketch that has been taught. Players at this stage only connect the circuit regardless of the type and color of the cable. The simulation is in two-dimension and will be made as a standard EWD sketch practice. Figure 1 shows the initial display of the first stage before started and figure 2 shows the display when all cables in the circuit are connected. The learning target designed at the first stage is to measure students' ability to understand the concept of electrical circuit models.

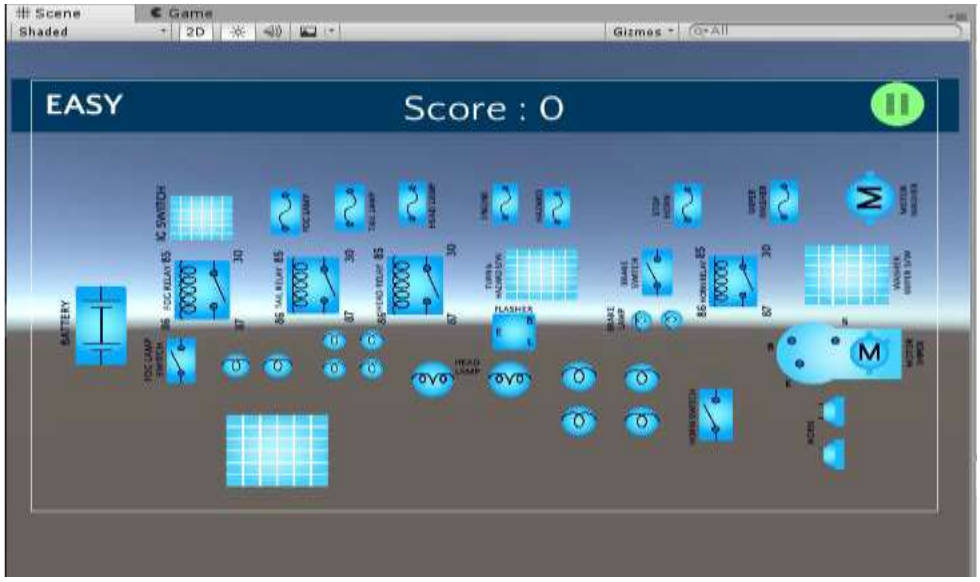

Figure 1: The initial interface at the first stage

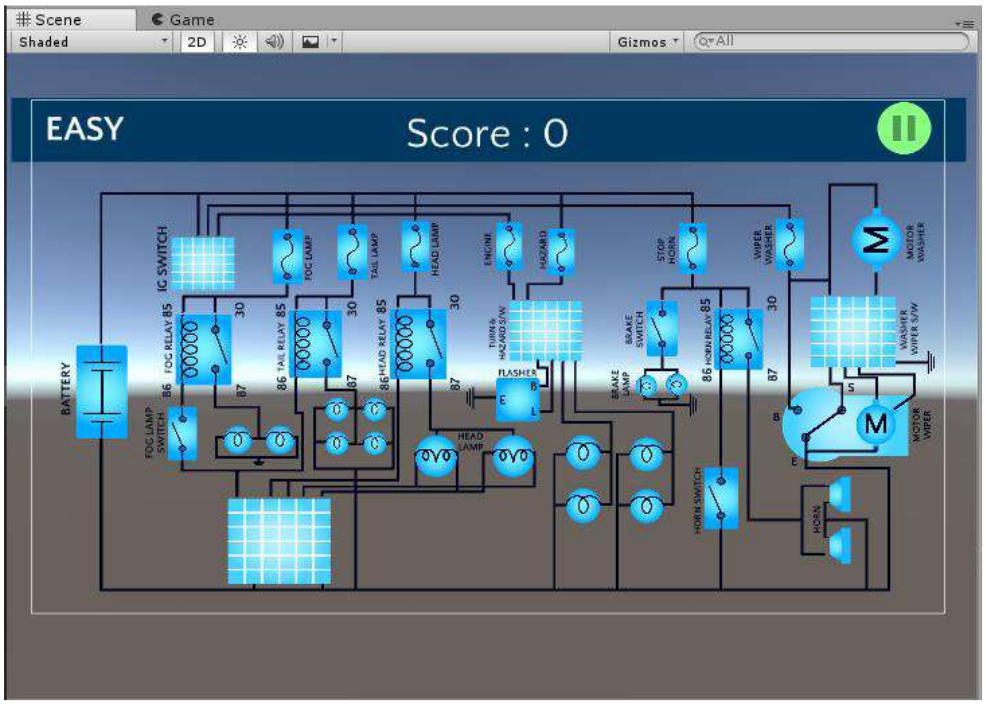

Figure 2: Display when the first stage has completed

Received: 27 Mar 2020 | Revised: 20 Apr 2020 | Accepted: 05 May 2020

2) Stage 2-Real EWD (Medium)

Simulation on the second stage is quite similar to the first stage, and the difference is that the player must determine the type and color of the cable following the standard. There are two types of the cable under its electrical pole: red-colored cable for positive and dark green for negative. The work order requires the player to adjust the positive and negative currents of the circuit. Figure 3 shows the display that has been assembled in the simulator. The second stage is specifically designed to measure students' ability to understand the type of current in a circuit and to strengthen students' analytical skills in determining the indicate problem in a circuit.

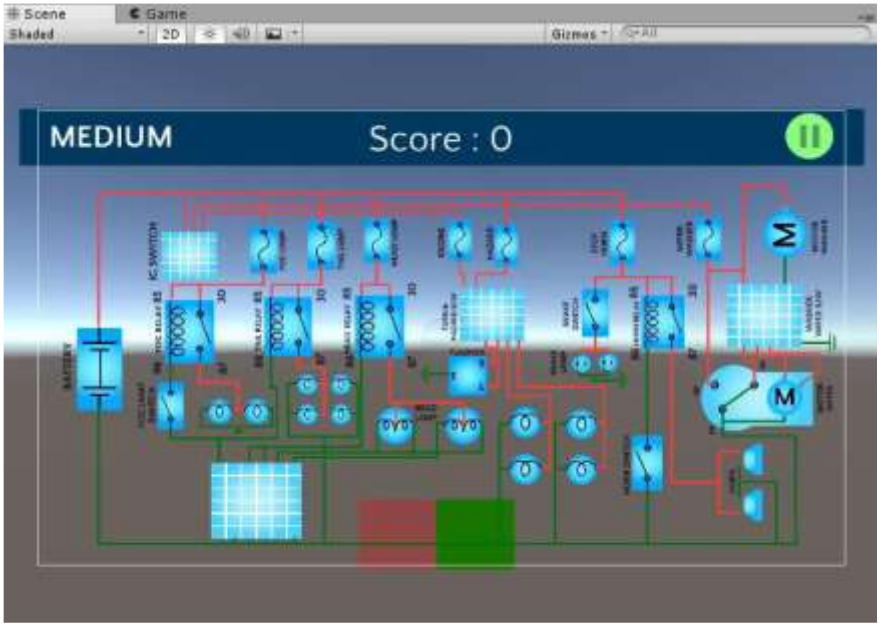

Figure 3: Display of the second stage that has completed

3) Stage 3-Real EWD with Truth Table (Hard)

Simulation on the third stage is essentially a combination of the first and second stages with the addition of a special mode for the combination switches table. Figure 4 showing the truth table for the combination switch. The third stage specifically allows players to measure their ability to arrange the circuits which involving combination switches and increase their analytical skills to see the path of electric current passing through a combination switch.

Received: 27 Mar 2020 | Revised: 20 Apr 2020 | Accepted: 05 May 2020

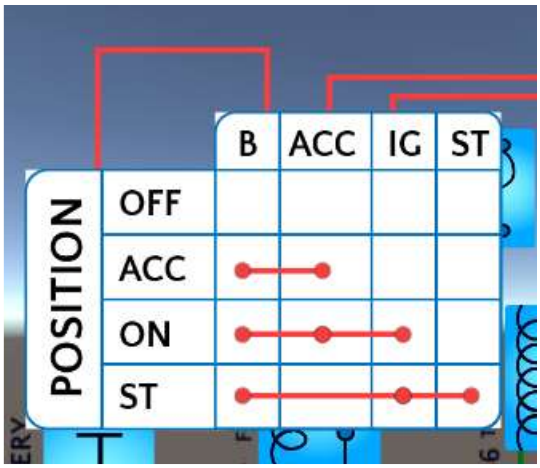

Figure 4: The truth table in combination switch

IV TESTING AND DISCUSSION

The testing phase is divided into two phases; alpha testing conducted by the authors and team to ensure the media runs well and correctly, while beta testing is intended for respondents (teachers and students) who directly try this media. After the beta testing is complete, respondents are given a questionnaire to assess this learning media. Beta testing involved five automotive teachers and 30 students from grade 12th automotive majors. The test procedure was carried out by asking respondents to play the simulator. After completion, the respondent fills in their biodata and assessment sheet in the form of a questionnaire. Aspects tested in beta testing are:

(1) General aspects relating to the benefits provided by the use of this learning media;

(2) Specific aspects related to user interface functionality, the level of ease of use of the media and the smoothness of the media on the installed device.

Questionnaire data collected was then recapitulated for further interpretation of simple scores using equations:

$$Index\ (\%) = \frac{\sum(T\ x\ P_n)}{N\ x\ P_{nMax}}$$

Where T is the total respondent who chooses the choice, P_n is the chosen score, N is the total respondent, and P_{nMax} is the highest chosen score. Table 1 shows the test results for teachers and Table 2 for the students.

Table 1: The questionnaire responds from teachers

No.	Questions				
1	The material in the learning media is in suitable with the automotive electrical wiring diagram models				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	3	2	0	0
	T x P_n	12	6	0	0
	Index (%)	90%			
2	The simulator is easy to use				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	3	2	0	0
	T x P_n	12	6	0	0

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No.	Questions				
	Index (%)	90%			
3	The simulator runs well on the device (computer for the teacher, mobile phone for students)				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	3	2	0	0
	T x P_n	12	6	0	0
	Index (%)	90%			
4	The functions of the menu buttons are correct and working properly				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	4	1	0	0
	T x P_n	16	4	0	0
	Index (%)	95%			
5	The feature is easy to understand				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	2	3	0	0
	T x P_n	8	9	0	0
	Index (%)	85%			
6	This game helps the learning process for automotive electrical wiring diagram				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	3	2	0	0
	T x P_n	12	6	0	0
	Index (%)	90%			

Table 2: The questionnaire responds from students

No.	Questions				
1	The material in the learning media is in suitable with the automotive electrical wiring diagram models				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	16	14	0	0
	T x P_n	64	42	0	0
	Index (%)	90%			
2	The simulator is easy to use				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	12	18	0	0
	T x P_n	48	54	0	0
	Index (%)	85%			
3	The simulator runs well on the device (computer for the teacher, mobile phone for students)				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	13	17	0	0
	T x P_n	52	51	0	0
	Index (%)	85.8%			
4	The functions of the menu buttons are correct and working properly				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	12	16	0	0
	T x P_n	48	48	0	0
	Index (%)	81.7%			
5	The feature is easy to understand				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	16	13	0	0
	T x P_n	64	39	0	0
	Index (%)	87.5%			
6	Feedback at the end of the level helps to improve the ability to understand the electrical wiring diagram				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	16	14	0	0
	T x P_n	64	42	0	0
	Index (%)	90%			

No.	Questions				
7	The simulator helps for learning automotive electrical wiring diagram				
	Response	Strongly Agree	Agree	Disagree	Strongly disagree
	Answers	16	14	0	0
	T x P_n	64	42	0	0
	Index (%)	90%			

Furthermore, the results of the score index are compared to the Likert Scale criteria intervals. The index scores, according to the questionnaires, respond are as follows:

Table 3: The index scores from the questionnaire

Question	Teachers		Students	
	Index (%)	Criteria	Index (%)	Criteria
The material in the learning media is in suitable with the automotive electrical wiring diagram models	90 %	Strongly Agree	90%	Strongly Agree
The simulator is easy to use	90 %	Strongly Agree	85 %	Strongly Agree
The simulator runs well on the device (computer for the teacher, mobile phone for students)	90 %	Strongly Agree	85.8 %	Strongly Agree
The functions of the menu buttons are correct and working well	95 %	Strongly Agree	81.7%	Strongly Agree
The functions of the menu buttons are correct and working properly	85 %	Strongly Agree	87.5%	Strongly Agree
This game helps the learning process for automotive electrical wiring diagram	90 %	Strongly Agree	N/A	-
The simulator helps for learning automotive electrical wiring diagram	N/A	-	90%	Strongly Agree
Feedback at the end of the level helps to improve the ability to understand the electrical wiring diagram	N/A	-	90%	Strongly Agree

As we can see from Table 3, both the students and the teacher show an obvious response that they agree with the benefits of this game. During the test session, both students and teachers were enthusiastic about finishing the challenge. We received an extra request from students and teachers to create another game model for different electrical wiring diagrams (i.e., ignition system and charging system).

V CONCLUSION

According to the response from respondents, it is clear enough that the simulator provides many benefits, both from students and for educators. The most important point is that this media can change the perception or general understanding that relating to the vehicle's electricity or EWD is difficult material. It is what gives the writer and team their satisfaction when the application is tested and sees students feeling enthusiastic about using it and giving a positive response to this simulator.

Apart from the many positive responses, of course, there are still some things that need to be developed again, such as increasing the variety of material and testing the validity of the simulator made involving many parties, especially from the automotive industry. After this application reaches the perfect stage, of course, the most important thing to do next is how to get this application disseminated more quickly to users (both students and educators) so that its usefulness can be immediately felt which in the end is certainly able to increase the

competence and understanding of participants students in terms of electrical wiring diagrams to improve the skills of students so they can be absorbed in the workforce.

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Received: 27 Mar 2020 | Revised: 20 Apr 2020 | Accepted: 05 May 2020