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Improvement of Metacognitive and Critical Thinking Skills through Development of the a 'Teaching Factory Based on Troubleshooting' (TEFA-T) Model in Automotive Vocational Learning

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ABSTRACT
The purpose of this research was to ascertain whether there had been any improvement in students' metacognitive and critical thinking skills through the development of the 'Teaching Factory Based on Troubleshooting' (TEFA-T) model in automotive vocational learning. The research had both quantitative and qualitative components and applied the 4D procedures, viz define, design, develop and disseminate. The subjects for the control and experimental groups were 32 students, and each was each group used an effectiveness test. The results showed that the TEFA-T learning model carried out the novelty value of the model syntax using the following activity steps: (1) identifying product problems, (2) defining the product problems, (3) generating and selecting several alternative solutions, (4) designing solving techniques, (5) ordering work contracts, (6) designing a product work schedule, (7) executing orders, (8) quality control, and (9) assessment. The test results showed that the TEFA-T Learning Model is valid using the Aiken'V formula and Confirmatory Factor Analysis (CFA) and Structure Equation Modeling (SEM), with a Chi-Square and x^2/df values of 219.76 and 0.8292, used to determine the model fit test (goodness-of-fit models). Furthermore, the practicality test declared it "Very Practical" with an average score of 4.56 and an Achievement of 90.02%. In conclusion, using the TEFA-T learning model to improve students' academic achievement, metacognitive, and critical thinking skills appeared to be effective (Sig. 2-tailed value is less than 0.05).

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Introduction

The rapid changes ushered in by the Industrial Revolution 4.0 era due to technological advancement have significantly affected human behaviour. For instance, in Indonesia, the pattern of living needs and the competency map needed by the workforce have changed (Moldovan, 2019). Educational institutions are accordingly expected to take a leading role in developing an accelerated programme. Educational and training institutions should prepare human resources capable of thinking, behaving, and acting creatively and flexibly in adapting to change (Chinedu et al., 2015;

Guile, 2019). However, this goal does not appear to be being met in many instances, as indicated by the low competence of graduates from educational institutions (Maksum & Purwanto, 2022).

Based on the needs analysis of learning in the automotive vocational field, students' learning processes and outcomes are not optimal. In research carried out at the Automotive Engineering Department of Automotive Engineering in January 2021, using a sample of 32 students in each class groups, 60% stated that the frequency method used by instructors was attractive. Furthermore, 65% stated that the traditional learning model was less appealing to students, as it was associated with weak metacognitive and problem-solving skills (Maksum, & Purwanto, 2019; Maksum et al., 2019; Güner & Erbay, 2021).

According to Junus (2019) and Karnain & Rashidah et al. (2018), students' inadequate critical thinking and metacognitive abilities lower their learning achievement. Instructors are less accustomed to demanding that students be more active and creative in obtaining information and seeking answers to questions raised in learning, making them more passive learners (Karre, Hugo, et al., 2019; Ministry of Education and Culture, 2016). The continuation of these learning conditions, with poor levels of interaction between students with both instructors and other students, makes it difficult to fully achieve course objectives (Khoiron, 2016; Jorgensen et al. 1995).

Research has been conducted to determine the best learning models for improving students' metacognitive and critical thinking skills to produce better graduates (Antonio & Prudente, 2021; Batlolona et al., 2019; Mataniari et al., 2020). Howard et al. (2001) stated that metacognitive self-regulation is a better predictor of problem-solving success. Research by Hollingworth & McLoughlin (2001) indicated that students' metacognitive skills could be significantly developed using a proactive approach and designing a specific environment for problem-solving. Livingston (2003) stated that metacognitive skills play a critical role in students' learning success which helps them to realise potential skills. Qiuye et al. (2009) in China surmised that iterative metacognitive theory can be applied to reform teaching methods of the electrical engineering practicum to make students more active in learning. Qiuye et al. (2009) applied a metacognitive-based learning model equipped with information technology facilities as a learning communication tool, which aims to produce graduates capable of facing and adapting to the new world of work. Eggen & Kauchak (2018) suggested that metacognitive skills help students to become self-regulated learners who are responsible for their own learning progress and adapt their learning strategies to achieve task goals. Jaewoo et al. (2014) reported that teachers need to create a metacognitive environment to promote good thinking skills directed at problem-solving and lifelong learning. Amin et al. (2019) described the relationship between metacognitive and critical thinking skills in applying learning strategies. Teachers and instructors are expected to improve the learning process through implementing active constructivist learning strategies. Yulianti et al. (2021) showed the effect of the Google Classroom-assisted blended-inquiry method on students' thinking skills, this method serving as a supplement to strengthen constructivist theory in learning design.

This research focuses on improving metacognitive and critical thinking skills through the development of the 'Teaching Factory Based on Troubleshooting' (TEFA-T) Model in Automotive Vocational Education. The model development is based on the link and match between industrial excellence and learning on campus based on systematic problem-solving such as troubleshooting. Synergising the advantages of the TEFA-T model is expected to solve problems systematically.

Numerous preliminary research developed the TEFA model of learning. For instance, Sutopo et al. (2017) applied a teaching factory (TEFA) learning model to improve subject competency skills for students and generate school income in vocational education. They argued that the application of this learning model can be guided by consumer needs, human resource capabilities, infrastructure and equipment effectiveness, project-based learning, increasing student skills through training, and developing marketing through print and electronic media. Azizah et al. (2019) stated that the application of the teaching factory model learning integrated with the production unit for student practice improves the quality of graduates ready to enter the world of work. According to Diwangkoro & Soenarto (2020), the main factors in developing this learning model in vocational schools are associated with management, production, marketing, and evaluation processes. Wahjusaputri et al. (2020) illustrated the success of the teaching factory model applied by vocational schools in Indonesia. Lestari et al. (2020) investigated teaching factory learning based on the business model canvas (BMC) in vocational schools. The results showed that applying the TEFA-BMC learning model could increase students' creativity. Widiatna et al. (2020) applied teaching factory based curriculum management in vocational education. The results showed that there was an increase in student competence so that they were ready to work in industry/business. Cholik and Soeryanto (2020) applying teaching factory based local advantages using the ADDIE model in vocational schools. Developing education by paying attention to local advantages with the TEFA learning model can produce competitive vocational education. Islami et al. (2021) applied teaching factory based learning management in vocational schools. The results of the study indicate that optimising learning management can increase the effectiveness of learning.

However, no research has been conducted to date specifically on the development of the 'Teaching Factory based on the Troubleshooting' learning model in improving metacognitive and critical thinking skills in automotive vocational education. This model involves industry-based learning by taking a systematic problem-solving approach through the process of problem identification, planning and problem solving. Therefore, this research aims to improve students' metacognitive and critical thinking skills by developing a Teaching Factory Based on a valid, practical, and effective Troubleshooting Learning Model in the automotive vocational learning. The operational goal is to produce a model capable of integrating theoretical learning with practice in a unified system. The research question is "How can the development and application of the teaching factory based on troubleshooting (TEFA-T) model improve metacognition and critical thinking skills in steering, brake, and suspension courses as part of automotive vocational learning?" This model is a learning breakthrough in automotive vocational learning to improve students' metacognitive and critical thinking skills and overall learning outcomes. The conceptual framework of this research is shown simply in Figure 2.

Teaching Factory

The teaching factory is a production/service-based learning model that refers to standards and procedures applicable in the industry (Louw & Deacon, 2020). Its implementation requires the absolute involvement of the relevant parties in assessing the quality of educational outcomes (Metternich et al., 2017; Chryssolouris et al., 2016). It also involves local governments and stakeholders (industry) in regulation-making, planning, implementation, and evaluation (Metternich et al., 2017; Martawijaya, 2013).

Metternich et al. (2017) and Chryssolouris et al. (2016) stated that a teaching factory is a learning concept in schools capable of bridging the competency gap between industrial needs and school knowledge. According to Mavrikios et al. (2018), a teaching factory makes learning in school workshops almost the same as activities carried out in an industry, which combines business concepts and vocational education. The basic principles of the teaching factory are as follows: a). There is an integration of work experience into the learning curriculum, b). All equipment, materials, and educational actors are arranged and designed to carry out the production process to produce goods and services, c). There is a combination of production-based and competency learning, and d). Students need to be directly involved in the production process to build their competencies (Welsh et al., 2020). Production capacity and product types are the main keys to successfully implementing production-based learning (Mavrikios et al., 2018). Subsequently, a teaching factory is a very effective and efficient model of learning activities (Mourtzis et al., 2018).

Some basic values that need to be developed to support teaching factory implementation include: a sense of quality, efficiency, creativity and innovation (Metternich et al., 2017; Karre et al., 2019). According to Metternich et al. (2017), the teaching factory concept educates students to work creatively and innovatively while practising problem-solving skills to measure creativity and determine new opportunities in the industry such as product designs. Due to the relationship between the implementation of the teaching factory to the production process of goods and services, the following three industrial disciplines need to be involved: a) Time discipline; producing goods or services within the targeted timeframe, b) Quality discipline; producing goods or services with the promised quality, precision, and proper composition, c) Procedure discipline; adhering to procedures sequentially because skipping one can have a negative impact on production results or the condition of machines/equipment. The relationship between industrial disciplines is related to the purpose of this research because the learning model applied is TEFA. Therefore, the learning concept applied is based on the existing work in the industry, which is related to the discipline to obtain a better production process and service.

Troubleshooting (Unstructured Problem)

Troubleshooting is a systematic approach to problem-solving that is often used to determine and remedy problems with complex machines, electronics, computers, and software systems (Watson, 2010; Elkins, 2009). It is the process of identifying, planning, and resolving problems or errors in software or systems on motorised vehicles (Elkins, 2009; Gauss et al., 2004). According to Moallem et al., (2019), the problems involved in troubleshooting are less structured in the sense that they contain complex situations with incomplete information to determine the solution (Naslund & Filipenko 2019). When information is collected and assessed, new opportunities for learning arise (Moallem et al., 2019). Naslund & Filipenko (2019) and Torp & Sage (2002) stated that less structured problems in troubleshooting are not given after students learning knowledge instead of the assignment model. The problem used in TEFA-T serves as a trigger for students to undertake research and gather the information needed to explore possible solutions (Louw & Deacon, 2020). Additionally, troubleshooting problems do not only contain one correct solution, but also open up opportunities for students' creativity and critical thinking, hence, they are able to use and integrate their existing knowledge to explore multiple solutions (Watson, 2010; Elkins, 2009).

Promentilla et al. (2020) used three criteria to distinguish between structured and less structured problems. These related criteria are the nature of the problem, the process, and the components of its solution (Waite et al., 2020; Joshi et al., 2020). Problems in troubleshooting are open, which means that the answers to these problems are uncertain (Waite et al., 2020). Therefore, TEFA provides opportunities for students to collect data and analyse motorised vehicle disturbances completely to solve the problems faced (Promentilla et al. 2020). The goal is to develop student metacognition skills, critical, analytical, systematic, and logical thinking to find alternative problem solving through empirical data exploration to foster scientific attitudes using TEFA-T (Saputro et al., 2020; Lawal et al., 2020).

Metacognitive Skills

John Flavell first introduced the theory of metacognition in 1976, since when different meanings and descriptions have evolved. Pang (2019) stated that metacognition is a process in which individuals think of their present self and carry out meaningful and memorable cognitive activities. Metacognition is one of the highest thought processes that manages and monitors peoples' mind use at the highest level of thought (Azevedo, 2020). Pang (2019) defined metacognition as "thinking about thinking," while Zhang (2017) defined it as "knowing the known and unknown." Furthermore, numerous definitions and descriptions have been widely given in education and psychology using the Flavell theory as a guide (Arroyo et al., 2021). In general, metacognition is a high-level thought process in the component of cognitive operations (Zhang, 2017). This means that it is used to monitor all strategies, procedures, skills, and sub-skills of the current teaching and learning process in the classroom. According to Pang (2019), metacognition refers to people’s knowledge and control over their thinking and learning activities. Azevedo (2020) asserted that metacognition is a fundamental structure because it affects learning. According to Veenman et al. (2014), metacognition refers to the awareness of individual thoughts and efforts to assess and monitor them.

Zhang (2017) stated that metacognition consists of two components, namely metacognitive knowledge and experience. However, Desoete (2001) stated that it consists of three components, namely metacognitive knowledge (declarative, procedural, and conditional), skills (planning, monitoring, and evaluation), and beliefs (self-concept, self-efficacy, motivation, attribution, and learning). Metacognitive knowledge refers to a person's knowledge of cognitive processes used to monitor those processes. Velzen (2017) also divided metacognitive knowledge into three categories, namely: (1) self or individual, (2) tasks or activities, and (3) learning strategies.

Metacognitive skills consist of awareness detection for design, monitoring, and assessment (Demirel et al., 2015; Railean et al., 2017). Velzen (2017) defined metacognition as knowledge individuals possess considering their individual thoughts, strategies, and efforts to monitor all these processes. It enables students to analyse, think about, and monitor their learning capabilities.

Torp & Sage (2002) stated that problem-solving ability refers to an activity that involves cognitive processes to achieve a goal. According to Wallace (2020), problem-solving consists of cognitive elements. It is a process that involves manipulating knowledge in a certain direction (Tachie, 2019; Heuzeroth & Budke, 2021). Problem-solving is a process that involves the manipulation of knowledge and has a specific direction. Railean et al. (2017) described a problem as a question that needs to be asked during a difficult situation. This means that when individuals encounter a problem or task, they need to think, consider the facts or the existing situation, and make decisions to find a solution.

Velzen (2017) stated that metacognitive knowledge includes variables that interact in various ways in cognitive activity. Therefore, metacognition is the main contributor to cognitive activity in understanding, reading, problem-solving, concentration, memory, and social cognition, in addition to various self-control and independent learning (Azevedo, 2020). Its usage allows students to select, evaluate, review, and complete various cognitive activities (Webb, 2021). In some complex learning domains, students need to use great analytical skills to solve various problems.

Darmawan (2020), Amin et al. (2020), and Demirel (2015) stated that metacognitive skills are one of the most critical components used in a framework to solve problems. Metacognitive skills are elements of intelligence in the cognitive system (Popandopulo et al., 2021). It is considered one of the important capabilities in carrying out control and management operations while responding to problem-solving activities (Heuzeroth & Budke, 2021). According to Hartman (2013), metacognitive knowledge comprises of design and self-management strategies that are essential in problem-solving. These two strategies are used to determine whether a student is able to solve a problem successfully (Popandopulo et al., 2021). Design is one of the strategies used to divide a complex problem into small parts for easy solving and achieve specific goals using specified procedures (Webb, 2021). Meanwhile, self-management refers to students' ability to make revisions and corrections efficiently during problem-solving (Popandopulo et al., 2021). The process of making personal revisions and corrections is essential, specifically when students are faced with vague and difficult problems. This process allows them to increase awareness of their learning activities (Railean, 2017). This research aims to increase metacognitive and critical thinking skills on the parameters of the ability to evaluate the results of work carried out to conclude the cause of the problem.

Critical Thinking Skills

Critical thinking is a mentally disciplined activity for reflective and reasonable thinking used to evaluate arguments or propositions to determine an action to be taken (Paul & Elder, 2020). Unlike other intelligences, this thinking process can be improved and developed without depending on age (Cottrel, 2017). It is also a cognitive ability and strategy used to increase the likelihood of expected outcomes, targeted, reasoned, and goal-oriented thinking to solve problems, formulate conclusions, calculate possibilities, and make decisions (Paul & Elder. 2020).

Cottrel (2017) stated that the importance of giving new ideas to students is to develop their reflective thinking. Meanwhile, teaching staff need to encourage students to ask questions and participate in discussions to obtain evidence-based answers to the information they receive (Chua, 2014). Actually, the concept of critical thinking described by Paul & Elder (2020) and Cottrel (2017) has similarities. Another meaning of critical thinking is a process of the human mind to describe or assess a picture from outside the self that is obtained by humans. If the picture is clear, then humans can take action or decisions about it. Information, data, and facts are obtained from observations, experience, common sense, and communication (Bensley & Spero, 2020).

According to Chua (2014), critical thinking activities are a process that does not stop at one point of conclusion. The reason is that if one reaches a conclusion based on the existing evaluation and information and then adds new information about the same then the process repeats itself and the conclusion may differ (Rutherford, 2018).

Therefore, critical thinking is a human skill used in processing cognitive potential (Tang, 2020). It is associated with the TEFA learning model, where students identify and solve given problems by determining the goals and objectives. This is carried out by solving problems, formulating conclusions, compiling alternative final solutions and making decisions (Paul & Elder, 2020).

Critical thinking also includes assessing, weighing, and concluding the supporting factors required to make certain decisions based on skills, knowledge, and specific experiences (Dekker, 2020). For students, critical thinking needs to be inculcated through training (Tang et al., 2020). Some of the ways of achieving this skill set are through asking questions, analysing things critically, completing projects (Bensley & Spero, 2020). Many experts believe that critical thinking is a skill that really needs to be targeted through training early (Ulger, 2018; Ayçiçek, 2021). Its formation needs to be emphasised in classroom teaching and learning processes (Bensley & Spero, 2020).

Critical thinking should be routinely and slowly trained and built by enabling students to practice the habit of asking questions when in doubt to obtain certainty, calm, and solid attitude choices (Paul & Elder, 2020). Its formation needs to be emphasised in the teaching and learning process in the classroom (Ayçiçe, 2021). Sternberg & Halpern (2020) stated that teachers and other instructors are too focused on the teaching and learning process compared to the formation of critical thinking among students while conveying knowledge. They need to develop this skill set among students (Bellaera, 2021) but their own lack of clarity in critical thinking causes confusion in assessing and evaluating good thinking (Chua, 2014).

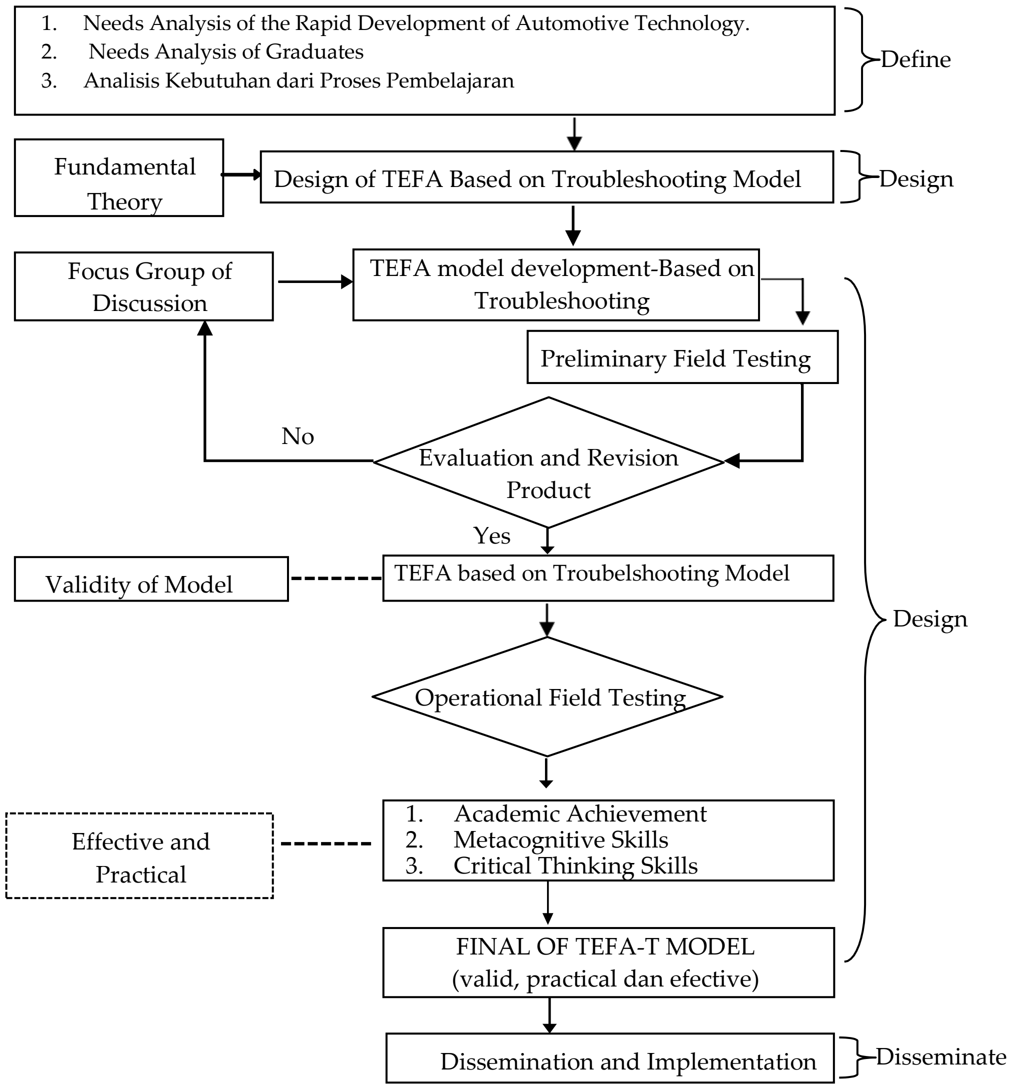
The measuring tools used to test critical thinking skills are developed from 5 specific subscales, namely analysis, evaluation, inference, deductive reasoning, and inductive reasoning (Facione & Gittens, 2016; Sternberg & Halpern, 2020). This research utilized the California Critical Thinking Skill Test (CCTST) due to its reputation and correspondence to the level of student studying in university.

Methods

The Research and Development (R&D) model with qualitative and quantitative approaches was used to carry out this research. The development of the TEFA-T learning model was carried out with actual R&D research, while Quasi-Experimental Design research, namely Non-equivalent Control Group Design, was used to test the effectiveness and impact of the developed model, therefore, it was called mixed-method. The mixed-method used refers to Creswell and Plano (2011) theory, which stated that the process of integrating two or more methods in a research increases confidence, leads to valid results, and prevents problems associated with methodological artifacts (Ladner, 2019). Qualitative methods were used to get a better understanding of the research results (Creswell & Plano, 2011). The TEFA-T model was developed using the 4D procedure, namely define, design, develop and disseminate, as shown in Figure 1. The activities carried out are conducting needs analysis, designing initial products, expert validation and product revisions, as well as small and large scale trials and characterized by those who take the Steering, Brake, and Suspension Systems courses, namely second-semester students of the Automotive Engineering Department. Data were collected from 32 subjects in the control and experimental groups and analyzed using the Aiken's v-test and Confirmatory Factor Analysis (CFA). Furthermore, the normality and homogeneity tests were carried out using the Shapiro Wilk Levene Test and t-independent, as shown in Table 1.

Figure 1

Model Development Stages



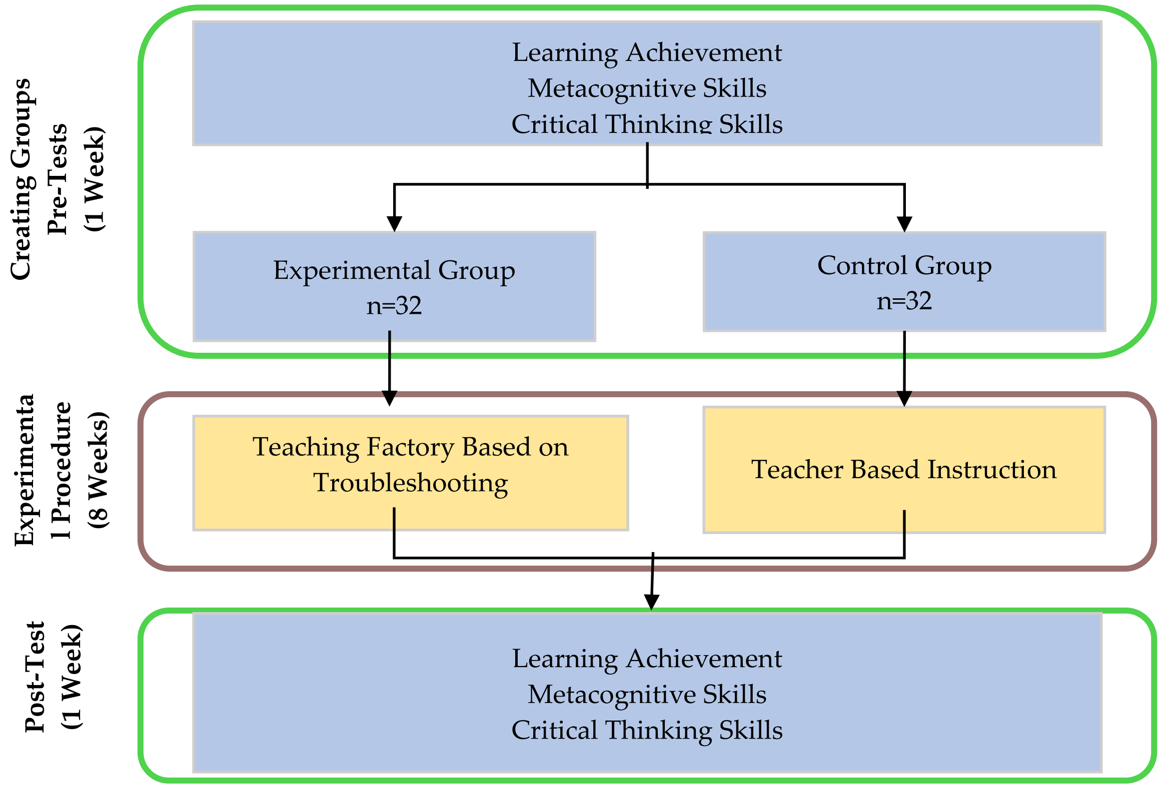
Experimental process

Model Effectiveness Test Design

The effectiveness test involved a quasi-experimental pre-test step between the control and experimental classes in the quantitative dimension over 10 working weeks. Pre-test activities were carried out for the control and the experimental classes in the first working week as shown in Figure 2. The two groups also explained the general and specific objectives of learning before the implementation of the research. This was followed by the implementation of two models in subsequent eight weeks, using the TEFA-T learning and teacher based models. After the experimental procedure was completed, a post-test was conducted in the tenth week, to measure students learning achievement, metacognitive, and critical thinking skills.

Figure 2

Experimental Design of TEFA-T Model Effectiveness Test Procedure.



Measuring and Data Collection Tools

Learning Achievement Test

An achievement test instrument was developed to determine the academic achievement of participants and measure the extent to which students had achieved learning objectives. A collection of 60 questions for each pre-test and post-test, with the same level of difficulty was used. After being validated by four experts, five questions were revised and the instrument was tested on 32 students who were not research subjects. The item difficulty index and item discrimination index were calculated. The result showed that fifty-five questions had an item differentiation index below 0.30, while the remaining four failed to match, and were excluded from the achievement test instrument. Therefore, only a total of 56 learning achievement test items are feasible to use. The average value of the discrimination index of the achievement test items, its difficulty index and coefficient of internal consistency are 0.45, 0.52, and 0.85.

Metacognition Skills Scale

Metacognitive skills were measured by adapting the scale developed by Schraw & Denison (1994), O'Neil & Abedi (1996), and Raja Gopal (2005) using a Likert Scale of 5 alternative options and

72 items consisting 12 main indicators. These include declarative, procedural, and conditional knowledge, design, information strategy management, monitoring, assessment, understanding goals, designing what is learned, providing focus, understanding and relating the concepts learned, and the process of remembering and reflecting on a lesson. Cronbach's alpha reliability coefficient of the scale was found to be 0.86 while the value for the sub-variable indicator was greater than 0.73 (Gliem & Gliem, 2003).

Critical Thinking Skills Scale

The measurement of students' critical thinking skills was adapted from the measurement scale developed by Facione, P & Gittens, C.A. (2016), called the California Critical Thinking Skill Test (CCTST). This test consists of approximately 34 Multiple choice questions that need to be completed in 45 minutes, which means 1.3 minutes per question. CCTST has questions found in most reasoning tests. The measurement components of critical thinking skills include (1) analysis, (2) evaluation, (3) inference, (4) deductive, and (5) inductive reasoning skills.

Result and Discussion

This section describes the results and discussion of the TEFA-T learning model research on Automotive Vocational learning to improve students' metacognitive and critical thinking skills. Metacognitive skills indicators include the knowledge of declarative, procedural, and conditional, as well as others including planning, information strategy management, monitoring, assessment, understanding objectives, designing what is learned, providing focus, understanding and linking the concepts, and remembering and reflecting on learning. The Critical Thinking theory reference in this research instrument is the California Critical Thinking Skill Test (CCTST) developed by Facione & Gittens (2016), with indicators such as (1) analysis, (2) evaluation, (3) inference, (4) deductive reasoning skills, (5) inductive reasoning skills.

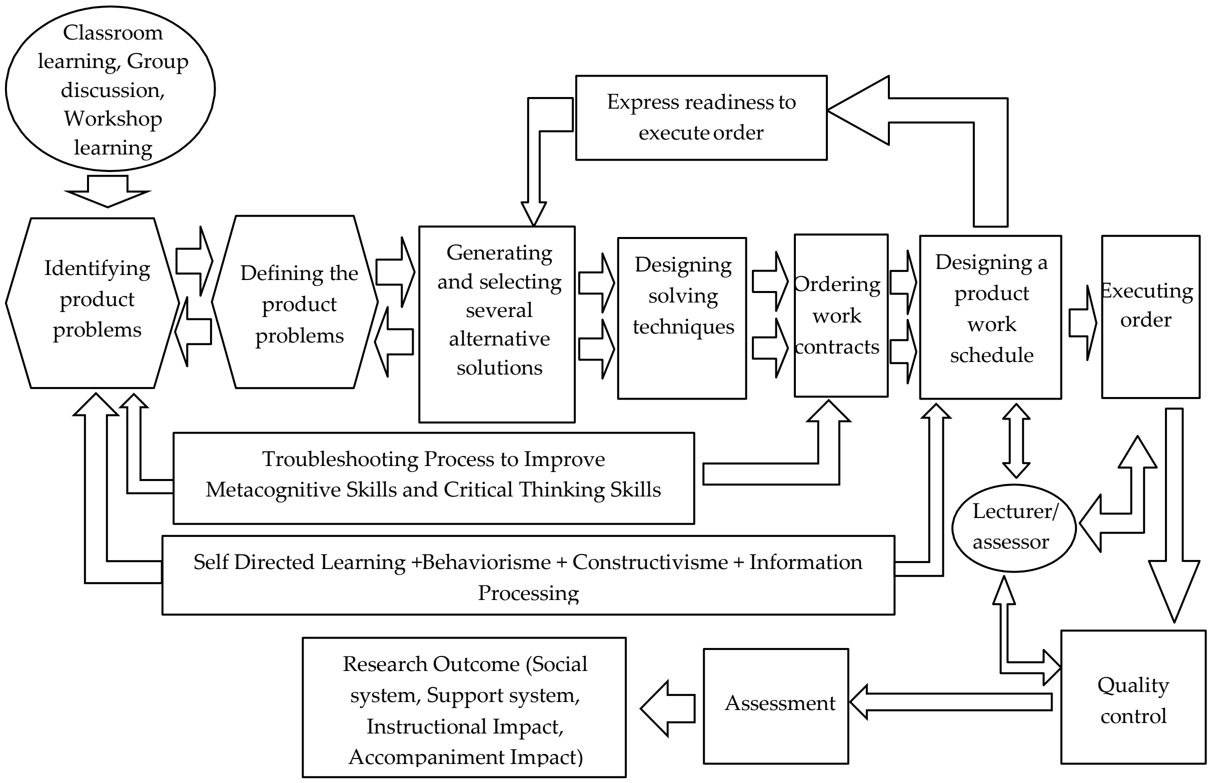
TEFA-T Model Development Results

Preliminary research was conducted to identify the skill problems in the existing Industrial Revolution 4.0 era, specifically for universities. It also identified the shortcomings of existing learning models and the availability of relevant models to solve skills-related problems. The previous results showed that metacognitive skills, critical thinking skills, and academic achievement are fundamental and global problems that need to be achieved. The availability of relevant models is the integration between the syntax of the TEFA and the concept of troubleshooting motorised vehicles into the TEFA-T. Therefore, a theoretical foundation is also needed for the developed TEFA-T model, which is constructed by integrating and analyzing the relevance and suitability of the TEFA syntax with the troubleshooting concept. The syntax theoretical analysis of the TEFA learning model consists of designing products, making, validating and verifying prototypes, manufacturing mass products, as well as presenting, analyzing, and evaluating works (Metternich et al., 2017; Chryssolouris et al., 2016; Mavrikios et al. 2018; Mourtzis et al., 2018, Karre et al., 2019; Welsh et al., 2020a; and Martawijaya, 2013). Meanwhile, the theoretical analysis of the troubleshooting process consists of basic concepts, such as defining, orienting, and organizing problems for learning, in order to provide individual or group guidance (Watson, 2010; Elkins, 2009; Gauss et al., 2004; Naslund & Filipenko 2019; Torp & Sage, 2002; Joshi et al., 2020; and Promentilla et al. 2020). The results of the Teaching Factory development based on the Troubleshooting model found that the syntax of the TEFA-T model as described in Figure 3.

The learning model developed is titled "Teaching Factory Based on Troubleshooting (TEFA-T) Model in Automotive Vocational Learning". The syntax and diagrams of the development results shown in Figure 3 consist of TEFA-T learning model namely; (1) the syntax of the Teaching Factory based on Troubleshooting Learning Model with nine steps consist of (a) identifying product problems, (b) defining the product problems, (c) generating and selecting several alternative solutions, (d) designing solving techniques, (e) ordering work contracts, (f) designing a product work schedule, (g) executing orders, (h) quality control, and (i) assessment; (2) a support system, such as TEFA-T model book, instructors manual, learning modules, and evaluation instruments; (3) instructional impact, namely increasing academic achievement which includes affective, cognitive and psychomotor, (4) social system, such as cooperation, and instruction between students and students, as well as students and lecturers, and (5) the impact of accompaniment, namely metacognitive and critical thinking skills.

Figure 3

Final TEFA-T Model Development Results



Validity Model

The data in Table 1 is obtained from the assessment results of the Construction Validity instrument, circulated to 16 lecturers who are considered experts. The validators involved pedagogical, vocational education, language, and automotive experts from the industry and developed fields. The TEFA-T model construction validity instrument includes a total of 70 question items. The validation test results of the TEFA-T model from this research are described in Table 1 as follows:

Table 1

Syntax constructs validation of TEFA-T model

No	Syntax construct validation	Chi Square > 0	P-value > 0,05	RSME < 0,05	$\frac{x^2}{df} < 2 \frac{x^2}{df} < 2$	Correlation index	Criteria
1	Identifying product problems	16.33	0.127	0.048	0.892	≥ 0.30	Valid/Fit
2	Defining the product problems	3.27	0.342	0.000	0.429	≥ 0.30	Valid/Fit
3	Generating and selecting several alternative solutions t	10.21	0.725	0.093	1.332	≥ 0.30	Valid/Fit
4	Designing solving techniques	20.12	0.169	0.049	1.511	≥ 0.30	Valid/Fit
5	Ordering work contract	14.65	0.309	0.037	1.726	≥ 0.30	Valid/Fit
6	Designing a product work schedule	12.91	0.238	0.000	0.782	≥ 0.30	Valid/Fit
7	Executing order	10.27	0.365	0.042	0.871	≥ 0.30	Valid/Fit
8	Quality control	21.53	0.075	0.045	1.024	≥ 0.30	Valid/Fit
9	Assessment	17.21	0.095	0.022	1.201	≥ 0.30	Valid/Fit
	Syntax Model of TEFA-T	13.87	0.813	0.00	1.415	≥ 0.30	Valid/Fit

Based on the results in Table 1, Confirmatory Factor Analysis (CFA) is used to determine LISREL. Furthermore, the 1-9 syntax test results showed that the p, - Root Mean Square Error Approximation (RSMEA) and the Chi-Square values are 0.99, 0.00, and 98.79. Therefore, it can be concluded that the syntax of the TEFA-T model 1-9 has fulfilled the goodness-of-fit model criteria. This is reinforced by the average value of the loading factor for each component that builds the syntax > 0.50, which means that there is a direct impact on every aspect. Based on this explanation, it can be concluded that the syntax and element 1-9 relationships are in a goodness-of-fit model, hence, the TEFA-T is valid (Stevens, 2009; Meyers et al, 2013).

Practicality Test of TEFA-T Model

The practicality instrument consists of 10 indicators of practicality aspects, namely instructions, learning objectives and indicators, syntax or learning phase, learning materials and methods, time allocation, language, physical form, benefits, and aspects of learning evaluation. The practical aspect is measured in writing, and those surveyed are related instructors and students. The results of the practicality test of the TEFA-T model from this research are described in Table 2:

Table 2

Syntax Practicality test for TEFA-T Model

TEFA-T model practicality test	Average score	Achievement percentage	Category
Practicality of model book			
Lecturer response	4.52	90.40	Very practical
Student response	4.59	91.80	Very practical
Practicality of the syntax model			
Lecturer response	4.49	89.80	Very practical

Student response	4.61	92.20	Very practical
Practicality of handbook			
Lecturer response	4.67	93.40	Very practical
Student response	4.39	87.80	Very practical
Practicality of Lectures Manual			
Lecturer response	4.53	90.60	Very practical
Student response	4.64	92.80	Very practical
Practicality of Students Manual			
Lecturer response	4.47	89.40	Very practical
Student response	4.60	92.00	Very practical

Table 2 shows the analysis result of practical test data used in the Research and Development (R&D) process, which obtained based on practitioner assessments and observations by instructors of 16 persons and total students of 64 persons, as well as responses or impressions from both parties. Practical observations were made in writing. The practicality test is implemented before the effectiveness test is performed. The practicality instruments of the TEFA-T model include practical aspects, namely attractiveness, ease of use, functionality, and usability, reliability, time sufficiency, level of implementation difficulty, and students responses (Moustapha, 2006). Table 2 also shows the results of the practical data analysis of the TEFA-T model and its supporting products, which indicates that the practicality level of all products is in the very good category. Based on the data, the practicality value of the TEFA-T model book is generally stated to be "Very Practical" with an average P-value of 4.56 or a mean of 90.02%.

The Effectiveness of the TEFA-T Model Implementation on the Instructional Impact

Effectiveness relates to the impact of implementing and complementing the TEFA-T learning model designed on the instructional impact, are learning outcomes, and critical thinking skills (Joyce & Calhoun, (2003). The effectiveness was measured after 8 learning meetings with the Quasi-Experimental Design research model. Those assigned to teach in this effectiveness test were instructors who had been trained the steering, brake, and suspension systems courses, both for the control and the experimental classes.

Table 3 shows differences in the pre-test and post-test scores for the control and experimental classes with a total of 64 students as subjects after ten weeks of implementing the TEFA-T model. The t-test was used to determine the difference in mean between two groups of unrelated samples. The results of the t-test posttest control and experimental classes showed that the value of Sig. (2-tailed) 0.000 has a significant difference between the posttest value less than 0.05. This means that both control and experimental classes at the end of the lesson have significantly different learning outcomes between the two classes. Therefore, it can be concluded that the experimental class student learning outcomes treated using the TEFA-T model were significantly higher than the control class using the conventional model. Learning in the conventional model using the teacher based instruction. It is conducted by instructors related to Steering, Brake, and Suspension Systems, who have been trained and prepared properly. The implementation of learning for the effectiveness test carried out after 8 lessons. The achievement test subsection shows that the instructional and accompaniment impact measurement was determined using a learning achievement test and adapted instruments.

Table 3

Syntax Pre-test and Posttest Scores

Variable	Control Class		Experimental Class	
	Pre-test Score	Posttest Score	Pre-test Score	Posttest Score
Valid	32	32	32	32
Missing	0	0	0	0
Mean	53.750	75.8667	51.300	87.733
Interquartile Range	8.88	16.00	10.62	10.88
Median	54.000	65.0000	53.000	81.000
5% Trimmed Mean	52.769	62.630	52.398	81.861
Std. Deviation	9.18033	9.44470	7.097	7.23346
Variance	84.278	89.202	50.372	52.323
Range	35.00	30.00	25.50	26.00
Minimum	35.50	59.00	37.50	72.00
Maximum	69.80	89.00	63.00	98.00
Skewness	-.424	-.035	-.126	0.22

This result is in line with Bensley & Spero (2020) and Diwangkoro & Soenarto (2020) research that TEFA effectively increases students' understanding through practical work-related application. They concluded that the more often students work through direct practical actions, the more trained their cognitive skills are related to the work. Mavrikios et al. (2018) carried out a research which produced the TEFA concept involving learning in three zones, namely the student involvement, educational institutions, and the industrial world. İt stated that the TEFA concept applied can improve students' cognitive aspects through continuous work.

The Effectiveness of the TEFA-T Model Implementation on Students' Metacognitive Skill

This research stated that the TEFA-T learning model is effective for improving students' metacognitive skills. The independent t-test result showed that the significance value of the metacognitive skills between the control and experimental classes was less than 0.05. This means that there are statistically significant differences in the learning outcomes of the metacognitive skill aspects in the experimental (learning using TEFA-T) with the control classes using the conventional model. Therefore, based on the findings, the effect of the TEFA model implementation on improving students' metacognition is quite large when compared to the conventional model. This means that the development of the TEFA-T learning model contributes to an increase in students' metacognitive skills in automotive vocational learning. According to Saputri & Corembima (2020), this increase is because the effect of strengthening students' metacognitive strategies in learning improves one's thinking skills. Learning tends to develop when students are more aware of their respective activities, such as having metacognitive awareness (Darmawan, 2020; Tachie, 2019). Instead, students need to orient themselves on the task and design the strategies needed to conduct it systematically and analyse its weaknesses and strengths.

Figure 4

Comparison of the Increase in the Student' Metacognitive Skills for Each Indicator

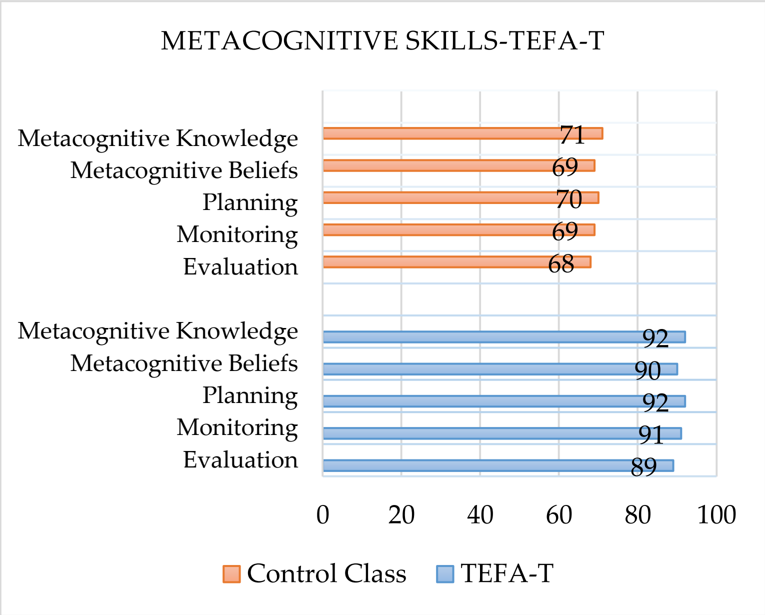


Figure 4 shows that after ten weeks of implementing the TEFA-T model, students that used it had better metacognitive skills for all indicators compared to the conventional approach. This model has the ability to improve students' metacognitive skills on all indicators of knowledge, beliefs, planning, monitoring, and evaluation, therefore, it can improve their academic achievement.

This finding is in line with the preliminary research, which stated that students' metacognitive skills are improved when teachers integrate metacognition in teaching (Saputri & Corembima, 2020; Arroyo González et al., 2021; Heuzeroth & Budke, , 2021). Therefore, through teaching, which provides space and opportunity to plan and monitor learning, students are able to reflect on the strategies used while completing learning tasks (Nongtodu & Bhutia, 2017). According to Metternich (2018), the TEFA model provides many opportunities for students to develop and practice metacognition through problem-solving activities. For example, when faced with problems, students need to plan possible steps, monitor the implementation process, and reflect on the steps to determine possible modifications (Liu & Min. 2020). Furthermore, the steps that promote students to think strongly, share views, and ask questions are expected to develop students' metacognitive skills (Dierdorff et al., 2021; Jackson, 2020).

Metacognition is considered one of the determining factors in knowledge transfer in learning because it is generally an activity to thinking (Muhlisin et al., 2018; Jackson, 2020; Heuzeroth & Budke, 2021). Furthermore, people's abilities to transfer knowledge in learning are associated with their success in problem-solving (Güner & Erbay, 2021). According to Bensley & Spero (2020), this shows that academically students with high ability tend to use metacognitive skills during the problem-solving process. Meanwhile, Webb (2010) and Schoenfeld (1985) stated that problem solvers in the beginner category had less metacognitive skills in monitoring, evaluation, and decision making when compared to those in the expert category. Bensley & Spero (2020) reported that metacognition is an essential element in determining the success or failure of a problem-solving technique. It becomes even more significant when associated with less structure (Tachie, 2019).

Furthermore, metacognition has a positive effect on learning, hence, adequate attention is needed to improve it through the academic environment (Veenman et al., 2014). Heuzeroth & Budke (2021) stated that the application of metacognitive strategies in the context of complex problem-solving processes is a big plus for overcoming linear, monocausal, multiperspective, and systemic thinking. This explicit teaching includes modelling, continuous metacognitive practice, and self-reflection on the learning process (Dierdorff et al., 2021; Railean, 2017). Teachers are also able to model metacognition by labelling their cognitive strategies while teaching (Railean, 2017). When teachers model their strategies, they are able to share conditional knowledge that informs their choices to use those cognitive strategies.

Implementation of TEFA-T on Students' Critical Thinking Skills

The accompaniment impact due to the implementation of the TEFA-T model is that students get hands-on work experience, which enables them to develop individual task skills. The impact of the next accompaniment is to train students to think critically during cases of disturbances in motorised vehicles on ways to make decisions about solving these problems by considering the positive and negative impacts.

Figure 5

Comparison of the Increase in the Student' Critical Thinking Skills for Each Indicator

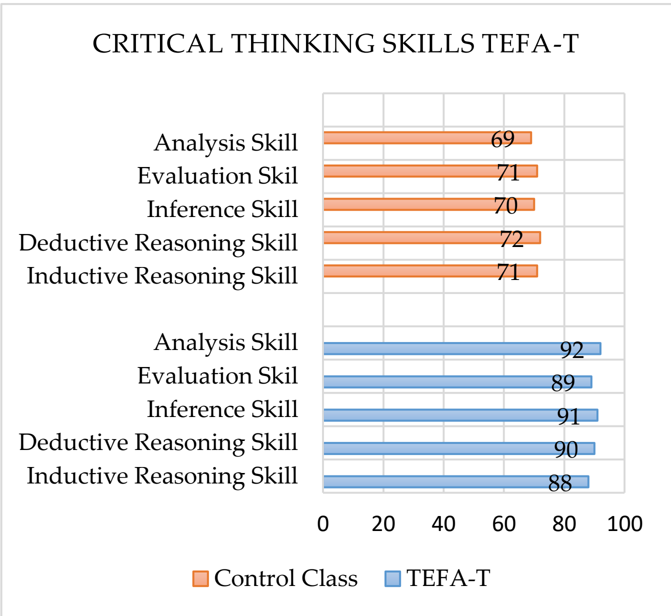


Figure 5 shows that after ten weeks of implementing the TEFA-T model, students that used it had better critical thinking skills for all indicators than conventional approaches. This also can improve students' critical thinking skills for all indicators, namely analysis, evaluation, inference, and deductive reasoning skills. This research reaffirms previous findings, where troubleshooting-based TEFA learning (unstructured problem) contributes to improve students' critical thinking skills, covering a broad spectrum of educational levels and disciplines, such as engineering (Syed et al., 2021; Gaus et al., 2004; Webb, 2010).

According to theory, mastery of knowledge is one of the prerequisites in developing students' higher cognitive thinking skills (Dewi et al., 2019, Brečka et al., 2020; Ren et al., 2020). Moreover, Toheri & Haqq (2020) stated the need to improvisational knowledge and working memory in a social environment and an attitude that continues to promote their critical thinking skills. Under this model, these skills are fostered through several processes such as problem identification, discussion, brainstorming and debate sessions, interactions, reflection, feedback, and mutual teaching (Syed et al., 2021; Abdurrahman, 2019).

Therefore, from the explanation above, it is concluded that troubleshooting-based TEFA-T can be used in the learning process where students are able to think and express opinions or ideas that differ from one person to another (Syed et al., 2021; Webb, 2010). This can generate a thought capable of solving a problem and developing new ideas that can be used for the benefit of many people (Kardoyo et al., 2020). In this learning, students are allowed to actively build knowledge, which is found, formed, and developed individually and in groups (Ayçiçek, 2021; Bellaera et al., 2021). This is because education is a social process that cannot occur without interaction between students. Subsequently, learning activities and working cooperatively in groups accommodate the development of critical thinking skills (Tohir et al., 2020; Sternberg & Halpern, 2020). Hence, the results align with the theory put forward by several authors and numerous experimental research of TEFA-T previously conducted on critical thinking skills items, which led to positive findings in the learning of various disciplines.

Conclusion

This research involved a Teaching Factory learning model based on Troubleshooting (TEFA-T model) with nine activity steps, namely: (1) identifying product problems, (2) defining the product problems, (3) generating and selecting several alternative solutions, (4) designing solving techniques, (5) ordering work contracts, (6) designing a product work schedule, (7) executing orders, (8) quality control, and (9) assessment. The last step is used to implement the syntax (stage) using supporting products such as learning model books, modules, instructors manual, and student manual. The novelty contains the syntax of the learning model to strengthen the aspects of metacognitive and critical thinking skills needed to solve troubleshooting problems. The results showed that the TEFA-T Learning Model was declared valid, both from the aspect of content and construct validity based on the validity test results using the Aiken'V formula, Confirmatory Factor Analysis (CFA), and Structure Equation Modelling (SEM), with a Chi-Square and x^2/df values of 219.76 and 0.8292, thereby fulfilling the goodness-of-fit model's test. The TEFA-T Learning Model was declared "Very Practical" with an average score of 4.56 and an Achievement percentage of 90.02%. Developing the TEFA-T learning model in automotive vocational learning increased students' knowledge, metacognitive beliefs, planning, monitoring, and evaluation by 29.58%, 30.43%, 31.43%, 31.88%, and 30.88%, respectively. Furthermore, critical thinking skills also increase their evaluation, inference, deductive, and inductive reasoning by 33.33%, 25.35%, 70%, 25.00%, and 23.94%, respectively. These results are obtained by comparing the control with experimental classes applied to the TEFA-T model in automotive vocational learning. This suggests that the application of this learning model can improve students' metacognitive and critical thinking skills.

Moreover, it is very effective in improving student academic achievement, namely the learning outcomes in the experimental (mean 87.733) and control classes (mean 75.8667) learning outcomes, which are significantly different, with a significance value of 15, 44, or 0.000 < 0.05. This model can significantly improve students' metacognitive skills on all indicators of metacognitive knowledge, beliefs, planning, monitoring, and evaluation, enhancing their academic achievement. This can also significantly improve their critical thinking skills for all indicators, namely analytical, evaluation, inference, and deductive reasoning skills. For education practitioners; instructors are recommended to implement the TEFA-T learning model in all courses because it has proven valid and effective. This model is easily adopted and implemented by students and instructors to improve their metacognitive and critical thinking skills, producing quality work in automotive vocational relevant to industry demands. Future studies need to develop this model in other fields.

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