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Validity of Empati STEM Learning Model to Increase Scientific Literacy and Technology Literacy

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ABSTRACT
Objective: Based on previous research, there is evidence that science literacy and technological literacy in various regions of Indonesia still need improvement, especially vocational high schools. Science literacy and technological literacy in science learning are combined with socioemotional abilities, one of which is the ability to empathize students. Learning interventions are needed to produce competitive graduates who are able to compete in facing challenges in the world of work. This study aims to validate the STEM Empathy learning model. **Method:** The educational development research design used is a validation study design that tests two criteria, namely testing content validity (also called relevance) and construct validity (also called consistency). This validation involved three experts in the field of Science Education, and the validation instrument used a validation sheet. **Result:** The research results and data analysis showed that the Empathy STEM learning model consistently provided highly relevant results and met strict validity and reliability standards (with a percentage of agreement ≥ 75%). **Novelty:** Validation of learning support devices includes lesson plans, student textbooks, learner worksheets, science literacy and technological literacy tests. Empathy STEM learning can be applied to improve students' science literacy and technological literacy. The empathy stem learning model can train scientific literacy and technological literacy while fostering students' socio-emotional abilities. STEM learners are well-suited to teaching empathy, social emotional learning into science education creating a holistic STEM that s the potential to increase students' interest and appreciation of science and its applications.

INTRODUCTION

The era of society 5.0 brings changes in the field of education including science literacy and technological literacy. These changes have improved the quality of human life along with the development of science and technology (Asih et al., 2022). Education aims to shape students to become agents of change with fundamental values in facing future challenges and increase students' understanding. The school environment, one of the learning centers in the community, must provide an environment that can develop their character through various activities in the learning process. Developments in science and technology cause new problems related to global issues, morals and ethics that can threaten human dignity and survival.

Industry requires qualifications for prospective workers to have hard skills (ability to master science and technology, theory), but must have soft skill characters (communication, empathy, and collaboration) (Prasetyo et al., 2020). Schools in Indonesia are still weak in teaching soft skills to students. Vocational High School is currently designed to produce graduates who are skilled, competent, and competitive, but there is still a gap between the material taught in Vocational High School and what is needed in the world of work. This gap is also a factor that Vocational High School graduates should be able to directly become a ready-to-train workforce, contributing greatly to the high unemployment rate in Indonesia. One way to improve the quality of human resources in Indonesia, especially vocational education, is the learning process in order to achieve a balance between hard skills and soft skills.

Science learning still emphasizes knowledge content and practices and ignores the social dimension of science education to develop the skills of learners required for students' active participation in society. A very important aspect that influences students to investigate and build creativity is the empathy factor. The importance of empathizing with the subject matter has to do with a holistic approach to teaching, social, emotional and cognitive dimensions can enhance the learning experience. Science literacy and technological literacy are key competencies to build human well-being in the present and future. Science literacy is one of the skills required in the 21st century among the 16 skills identified by the World Economic Forum. According to Aoun (2017) technological literacy is the ability to understand how machines and technology applications work. Therefore, STEM learning and empathy should be included in practicing science literacy and technological literacy to empower the next generation to answer global challenges in the midst of modern society.

The results of Sutrisna's research (2021) show that the average value of scientific literacy of class X high school students in Sungai Penuh city is 31.5, which is in the low category influenced by several factors, namely the evaluation tool has not led to the development of scientific literacy and students' reading interest is still low. The same thing was also done by Amahoroe (2020) involving 25 grade X vocational students in Cisarua, improving STEM-based science literacy obtained an N-Gain of 0.7, students' science literacy indicators experienced the highest increase in the aspects of interpreting data and scientific evidence and the lowest was using facts, reasoning concepts, and procedures.

The process of assessing science learning generally uses general questions that only measure students' cognitive learning outcomes in the form of summative assessments, for example, mid-semester assessments and end-of-semester assessments are the main ones, there is no feedback to students, so there is no improvement in students' science literacy competencies. In fact, formative assessment in the form of feedback is an essential component of classroom learning. A more appropriate way to assess science literacy in the form of a written test, for example, reading is sought to contain the context of life, illustrations of the process, or the results of the investigation in the form of text, images, graphs.

It is found that science learning in Indonesia that leads to the formation of science literacy and technological literacy in Vocational High School is still rarely done. In the context of STEM learning integration research that can improve students' empathy attitudes in Asia is still very limited. Therefore, in this study, the Empathy STEM model will be developed to train science literacy and technological literacy and will provide meaningful experiences for vocational students.

The main basis of the novelty of STEM E is the focus on measuring science literacy and technological literacy skills and encouraging students to understand contextual problems and then find solutions or innovations based on science and technology that also consider their impact on society. Empathy-based learning in STEM makes students more motivated because they see that what they learn can provide benefits to others. Many learning models have contributed to improving science literacy and technological literacy but are accompanied by knowing students' socio-emotional abilities, one of which is empathy. Therefore, the development of innovative learning models is needed. These learning models include problem-based learning or PBL, inquiry learning, discovery learning, project-based learning or PjBL.

RESEARCH METHOD

The research methodology employed is educational design research. The objective of development research is to create specific educational materials and assess the effectiveness of these materials. Several educational design research models have been developed, including Wademan's Generic Design Research Model (GDRM) (Plomp & Nieveen, 2013). The stages of GDRM development research (Plomp & Nieveen, 2013) are (1) Problem Identification, (2) Identification of tentative products and design principles, (3) Tentative products and theories, (4) Validation and prototyping and assessment of preliminary products. Stages 1 and 2 begin with identifying the problem and conducting a literature review. During stages 3, the researcher created a prototype Empati STEM learning model together with the necessary equipment. In stage 4, the results of the prototype Empati STEM learning model were validated.

The Empati STEM instructional model and resources were validated by three professionals in natural science education. The validators were three people with details: three doctor from the Universitas Negeri Surabaya. Validation is conducted by utilizing the outcomes of the evaluation of content validity and construct validation. Content validation consists of several aspects: (1) the clarity of the background of the model requirements, (2) the state of the art of knowledge, (3) the clarity of theoretical and empirical support, (4) the planning and implementation of the model, (5) the management of the learning environment (Nieveen & Plomp, 2013; Arends, 2012; Joyce, Well & Calhoun, 2009). Meanwhile, construct validation consists of several aspects: (1) consistency of the learning model, (2) consistency of theoretical and empirical support for the implementation of the learning syntax in the phases, (3) consistency of planning and implementation of the model, (4) management of the learning environment, (5) Assessment and Evaluation (Nieveen & Plomp, 2013; Arends, 2012; Joyce et al., 2009).

The data obtained from content validation (relevance) and construct (concictency) were evaluated using a qualitative statistical technique. This analysis was conducted to draw conclusions about the developed model and the quality of the assessment. Four scales were used to measure each component of the assessment indicators. Data analysis relies on the mean value of three validators. The assessment score is then converted into qualitative data using four criterion scales in Table 1.

Table 1. Criteria for the validity of the Empati STEM learning model.

Score intervals	Criteria	Description
$3.6 \le P \le 4.0$	very valid	It can be utilized without any need for modification
$2.6 \le P \le 3.5$	valid	Can be utilized with slight modifications
$1.6 \le P \le 2.5$	quite valid	It is compatible with different versions
$1.0 \le P \le 1.5$	invalid	It is inoperable and necessitates consultation

The dependability of the model validation instrument and supporting tools for the Empati STEM learning model is determined by calculating the inter observer agreement. This is done by statiscally analyzing the percentage of agreement (R), as described by Borich (1994). Model validation instrument and Empati STEM learning model tools are considered reliable if they have a percentage value equal to or greater than 75.0% (Borich, 1994).

RESULTS AND DISCUSSION

Results

Learning model can be categorized according to desired learning outcomes, the syntax of the model, and the learning setting. Learning objectives are the final results expected based on predetermined plans. The learning model's syntax consists of sequential phases or steps that are followed during the learning process. The learning environment is the context in which learning must be carried out, including improving student motivation and conditioning (Arends, 2012). There are five main components in a good learning model, namely: (1) syntax, (2) social systems, (3) reaction principles, (4) support systems, and (5) instructional impacts and accompanying impacts (Joyce et al., 2009). The Empati STEM hypothetical model used to increase scientific literacy and technology literacy consists of five phases, namely: (1) Define the Problem, (2) Empathy and Collaboration, (3) Plan and Design Prototype, (4) Monitoring and Application, (5) Evaluation. An overview of the Empati STEM model syntax is in Figure 1.

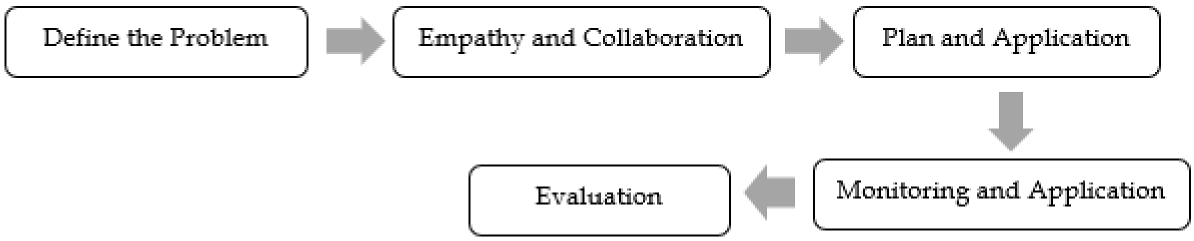

Figure 1. Empati STEM model syntax.

The syntax of the Empati STEM model is described in learning activities at each phase, which are equipped with learning achievement indicators that will be developed at each stage of the model. Learning activities are arranged based on suitability to the aims achieved in each phase. Learning activities in each phase are equipped with learning achievement indicators for scientific literacy and technology literacy, which will be developed at each stage of the Empati STEM model in Tabel 2.

Table 2. Relations of syntax, learning activity indicators of learning outcomes.

Syntax	Learning Activities	Learning Achievement Indicators	
		Scientific Literacy	Technology Literacy
Phase 1, Define the Problem	Observe learning videos of phenomena related to energy and change	Explaining phenomena scientifically	Apply design concepts, scientific principles to solve problems in daily life
Phase 2, Empathy and Collaboration	Ask questions about the dangers of negligent use of irons.	Explaining phenomena scientifically	Apply design concepts, scientific principles to solve problems in daily life
Phase 3, Plan and Design Prototype	In groups, understand the flowchart of designing a project	Design and evaluate scientific investigations	Apply design concepts, scientific principles to solve problems in daily life

Syntax	Learning Activities	Learning Achievement Indicators	
		Scientific Literacy	Technology Literacy
Phase 4, Application	Monitor the designed project and test it.	Interpret data and evidence scientifically	Evaluate the impact and consequences of technology on society
Phase 5, Evaluation	Present and share experiences during project completion	Communicating the process and results of their learning and self-reflection	Develop personal interests and abilities related to careers in technology

The validity of the learning model resulting from development research must meet the aspects of relevance and consistency. Testing the model's validity includes testing the content and construct validity of the prototype of the learning model being developed. The content validity of the learning model assesses the need for model intervention, and the model has been designed based on the latest scientific developments. In contrast, construct validity assesses how the intervention model has been designed constructively and logically (Plomp & Nieveen, 2013). The validators of the learning model are three natural science education experts. The validator evaluates the model that has been developed using a model validation instrument with several assessment aspects. The results of content validation and construct validation of the Empati STEM model and test reliability are in Table 3.

Table 3. Results of content validation, construct validation and reliability.

No	Component Statement	Average	Validity category	Reliability	
				Reliability value	Reliability category
1	Aspects of STEM Empathy Model Development Needs	3.9	very valid	93.0%	reliable
2	Aspects of state of the art knowledge	3.7	very valid	90.0%	reliable
3	Aspects of Learning Model Components	3.7	very valid	90.0%	reliable
4	Aspects of STEM Empathy Model Overview	3.8	very valid	91.0%	reliable
5	Aspects of Theoretical and Empirical Support Appropriateness	3.7	very valid	89.0%	reliable
6	Implementation and Planning Aspects of the Empathy STEM model	3.9	very valid	93.0%	reliable
7	Aspects of the Learning Environment of the STEM Empathy Model	3.8	very valid	93.0%	reliable
8	Assessment and Evaluation Aspects of the STEM Empathy Model	3.7	very valid	86.0%	reliable
9	Language Aspect	3.8	very valid	86.0%	reliable
10	Display Format Aspect	4.0	Very valid	100.0%	reliable

Learning tools are also developed to support the implementation of the Empati STEM model, which is oriented towards developing science literacy and technology literacy. The construct and content validity of the Empati STEM model learning tools measure the consistency and logic of the learning model support tools that have been developed. The tools tested for validity include learning plans, student activity sheets, student text book, a science literacy and technology literacy test, and empathy questionnaire. Three validators assessed the validity of the learning tools supporting the Empati STEM model developed by the researcher using the validity instrument sheet provided. The validation findings of the Empati STEM model learning tools are presented in Table 4.

Tabel 4. The results of the Empati STEM model learning tools validation.

No	Component Statement	Average	Validity category	Reliability	
				Reliability value	Reliability category
1	Learning plans	3.8	very valid	93.0%	reliable
2	Student book	3.8	very valid	93.0%	reliable
3	Student Activity sheets	3.8	very valid	93.0%	reliable
4	A Science literacy and Technology literacy test	3.8	very valid	93.0%	reliable

Discussion

The validation results of the Empati STEM learning model, conducted by three validators specialized in natural science education, indicate that both the content validity and construct validity of the Empati STEM model fall inside the highly valid and reliable category. The Empati STEM learning model that has been developed has syntax, social systems, reaction principles, support systems, instructional impacts and accompaniment impacts. The learning model that has been developed has five syntaxes: (1) Define the Problem, (2) Empathy and Collaboration, (3) Plan and Design Prototype, (4) Application, (5) Evaluation. The Empathy STEM learning model allows for social systems in the first phase, fourth phase, and fifth phase. In the first phase students begin to recognize and understand social issues relevant to the context of science and technology. They are involved in discussions that encourage them to empathize with others, especially those affected by the problem.

This reaction principle is found in the Empathy STEM learning model as teachers should not be rigid and flexible. Teachers should be able to read the situation and condition of the students, and adapt the learning approach to their ability and learning style. This shows that teachers do not just rely on fixed methods, but adapt in ways that can optimize student understanding. Content and construct validity are very good, there are three things that are fulfilled by the Empathy STEM learning model: there is a need for model development, up-to-date knowledge, and the fulfillment of learning model components. The need for model development shows that Empathy STEM is developed based on problem identification, through preliminary study activities (Plomp & Nieveen, 2013). In Table 3, the results of the assessment in this aspect obtained an average of 3.8 including the excellent category with a percentage of agreement of 93%. It can be concluded that the design of Empathy STEM has fulfilled the components of the model is valid.

Learning to train science literacy and technological literacy requires special design with various forms of activities, such as linking issues involving technology and science concepts that are relevant to everyday life, through a scientific approach in learning and designing prototypes. Based on Table 4, the measurement of the content validity of lesson plans, student textbooks, learner worksheets, and science literacy and technological literacy tests obtained an average value of 3.8 very valid categories, a reliability value of 93.0% reliable categories. Thus the level obtained percentage of agreement exceeds 75.0% so it can be concluded that the validity of the feasibility of science literacy and technological literacy test items is very good.

Content validity is included in the excellent category, meaning that the Empathy STEM design made in the form of a model book both aspects of Empathy STEM development needs, aspects of state of the art knowledge and aspects of learning model components have met all elements of the learning model development criteria. The reliable category means that the three validators in assessing the content validity of Empati STEM are not much different or have consistent results.

In the Empathy STEM learning model student activity sheet, students write their own experimental procedures. In addition, in this student activity sheet there is a concept understanding section that can help students carry out discovery activities in the experimental process and is enabled to train science literacy and technological literacy. The science literacy and technological literacy test refers to the PISA indicators and contains a number of problems that require students' thinking skills at a high level based on Bloom and Anderson's taxonomy levels. The test was developed in the form of multiple choice questions that refer to Bloom and Anderson's taxonomy which contains knowledge dimensions from level C1 to C6. This test was developed consisting of 11 multiple choice questions for pre-test and post-test.

Learning to train scientific literacy and technological literacy requires special design with various forms of activities, such as linking issues involving technology and science concepts that are relevant to everyday life, through a scientific approach in learning and designing prototypes (Santosa et al., 2024; Patigu, 2024; Nugraha, 2019). Learning to train scientific literacy and technological literacy requires special design with various forms of activities, such as linking issues involving technology and science concepts that are relevant to everyday life, through a scientific approach in learning and designing prototypes (Santosa et al., 2024; Patigu, 2024; Nugraha, 2019). Based on the analysis of the results of the assessment of the validity of the format, language, and content of the three validators, the research hypothesis can produce learning models, student textbooks, student worksheets, scientific literacy tests and technological literacy to train students' scientific literacy and technological literacy in natural and social science subjects has been proven true.

CONCLUSION

Fundamental Finding: The Empathy STEM learning model developed is valid, practical, and effective to train science literacy and technological literacy of vocational students. **Implication:** The Empathy STEM learning model is designed to emphasize the development of technical skills as well as the ability to empathize in order to create students who are not only intellectually intelligent, but also able to understand the needs and problems of society. By understanding the needs of society, students can produce useful technological innovations. This is in line with the needs of the workforce in the 21st century which requires not only technical expertise, but also interpersonal skills to work in diverse teams. **Limitation:** Students still lack understanding of scientific inquiry skills, in terms of formulating problems, formulating hypotheses, determining investigation variables, designing experimental steps, analyzing data, drawing graphs from experimental data, and concluding. **Future Research:** Researchers can explore the use of digital technology or interactive media to enrich the learning experience and support empathy development through technology-based simulations or case studies.

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