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STEM Challenges as Solutions in Learning Over the Past 10 Years: A Systematic Literature Review

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Abstract

STEM learning guideline has been applied by several countries for decade. STEM disciplines have the synergy of interdisciplinary. It makes STEM have many advantages in improving students's understanding and solves problem to face future challenge and improving human resource competency. This study examined to find out how STEM is implemented in school, the challenges when STEM aplication and can be STEM as solution for future education. The research applies a systematic literature review. Data colllected with finding journals, articles and other scientific works with the help of search engines and sorted with PRISMA-P, and 50 journals were obtained that met the inclusion criteria. The result present a positif benefit in STEM education. Ability of student in various grade show increased in critical thinking, problem solving and technology mastery. The role of educator as facilitators hold the important aspect. Skill to make learning plans is a challenge because it determines a STEM project. STEM which is related to solving concrete problems can be the answer in facing today's global conditions that demand the creation of quality and competent human resources.

Keywords: learning · STEM · Trens of the last 10 years

INTRODUCTION

STEM (Science, Technology, Engneering and Mathematic) education has been aplied since 90s in America (Chan & Nagatomo, 2022; Ilma et al., 2023). The knowledge and science aplication is leading in called profound technology change around the word over a decade ago (Ross et al., 2022). STEM education has long been crucial point of interest government educators and industrial learder (Chiu et al., 2025). Science and technology can ensure good quality education by facilitating the integration of technology into the learning process (de Jong et al., 2014). Science and technology have a significant impact on the development of new teaching resources in the era of globalization because of the integration between these two fields (Gao et al., 2020).

The journal and research grow rapidly to advance multidisciplinary STEM (Simamora et al., 2024). Based on past STEM research, STEM bring cognitive, critical thingking, procedural mastery, and attitude benefit (Ardianti et al., 2020). STEM education approach can helping students develop literacy that will be necesaary as 21st-century citizens and professionals(Baran et al., 2021; Keleman et al., 2021). The importance of STEM is necessity to learn more about the implementation in the class, the tradition method still be found and STEM as collaboration

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between interdisciplinary (Fajrina et al., 2023). Despite many calls transformation of STEM model education, teacher must be adopt the method that match with student and environment condition. Because different educational and cultural conditions in each region (Sellami et al., 2024). In reality, gaps will be found both in terms of teachers and students. This paper discuss about three issue, out how STEM is implemented in school, the challenges when STEM aplication and can be STEM as solution for future education.

Conceptual foundation of this study based on similiarity research STEM education. In earlier journal found identifying seven research area such as policy, curriculum in STEM education, K-12 teaching, K-12 STEM learner, post secondary teaching, post secondary TEM learner, cultural gender issue and perpective about STEM educatin (Chiu et al., 2025). Qatar and United Arab Emirates (UEA) use STEM to improve student performance (Kayan-Fadlelmula et al., 2022). Also another country like Japan, Australia, UK etc use STEM to advancing teacher and student learning STEM (Chen et al., 2025; Darmawansah et al., 2023; Davis et al., 2025; Emembolu et al., 2025; Mutakinati et al., 2018)

Development country consider modelling education use STEM to improve student ability to (Indranuddin et al., 2024). Developing countries are considering educational modeling using STEM to improve students' ability to compete in the technological era (Li & Xiao, 2022; Rochim et al., 2022) One of the most prescriptive areas of application of STEM technologies education is the modeling and processes (Usembayeva et al., 2024). Critical thinking and complex problem solving skills are expected to solve complex problems in the future (Afifah et al., 2019)

STEM achieves the goal of transforming education into a real-world problem-based one (Santangelo et al., 2021). In STEM, teachers provide treatment to students through learning stages (Setyawati et al., 2022). After the basic concepts are delivered, they are then given stimulus to solve real problems with the help of science and technology (Indranuddin et al., 2024). This cycle is very helpful for students to apply in their daily lives, and often also increases interest in entering professional fields related to STEM (Purwati et al., 2024). Qualified professional STEM is needed in 21 century to fill demand society which is not far from computerization and technology (Baran et al., 2021).

Integrated STEM education have 5 pillar. There are Integration of STEM content, problem centered learning,inquiry based learning, design based learning and cooperative learning (Thibaut et al., 2018). This theoretical framework introduced by Thibaut et all (2018),the first category is integrating of STEM content, although STEM have 4 point, each subject learn separately in different teacher and classes. Student skill across discipline must be provide, because making integration in 4 different lesson is critical. Student individual knowledge should be provide, so they can focus on learning STEM and reach goal standard STEM curriculum.

The second category is focus on problem. The real problem tied to motivating student to resolve, so the design usually problem based learning. The purpose of problem based learning to stimulate student can open minded and focus transferring knowledge into realistic contexts. In that way, student can link knowledge and skill like activate mental model to process new information and experiences, solve messy problem to find several alternate solution. (Thibaut et al., 2018). The third category include instructional practices uses inquiry. Experimental learning applied to develop concept and knowledge, making prediction by making planning,

designing experiment and collecting data. Series activity occurs capability in mathematic and technological context (Thibaut et al., 2018). Teacher given topic to identify new idea, design, investigation and discover new concept. Teacher create guidance with questioning student to assist them find reasoning, research design and make solution. Because pure discovery can effective find because student can not spontaneously concept across different representation (Thibaut et al., 2018).

Design is the fourth category, engineering design process has open ended, authentic, hands-on and multidisciplinary. Student must carry out risk and uncertainly, consider prior experience and acquire study from failure. The fifth category discuss cooperative learning. Collaborative and cooperative learning needed to monitor the groups and refers all question back then. Student learn resolve group conflict on their own. Positive interdependence can be achieve through and so be stimulated. The five categories of instructional element most present different instructional practices. Integration of STEM content, refers to assimilation of learning goal, content and practices in different STEM disciplines (Thibaut et al., 2018).

STEM refers to student centered, because student develop better understanding in learning activity (Fadiarahma Vistara & Wijayanti, 2022). Through hand-on activities, student can actively learning and observe in daily activity and take innovation in. overall assessment used as a part of instruction. Assessment make student to connect all the part of STEM like mathematic, science, engineering and technology, arrange them and built a simple result. (Indranuddin et al., 2024). The globalization education STEM also have collaboration between stakeholder and government collaboration. Teacher as part of government employee need varios strategy to improve STEM participation, including curriculum reform, teacher initiating, and program systemic disparities (Khadisha et al., 2025).

METHODS

This study applies a systematic review with the PRISMA-P (Preferred Reporting Items for Systematic Reviews and Meta-Analyses-Protocol) method (Simamora, 2024). The search results based on this method produced 50 accredited journals from 2018 to 2024 that focused on the formulation of the problem and research topic and then carried out a structured process according to the PRISMA stages. According to Simamora in 2024, the stages in the PRISMA procedure include: Identification of literature that is in accordance with the research, analysis of criteria based on literature authors, analysis of the use of codes and themes by article authors and findings of literature analysis which are used as conclusions.

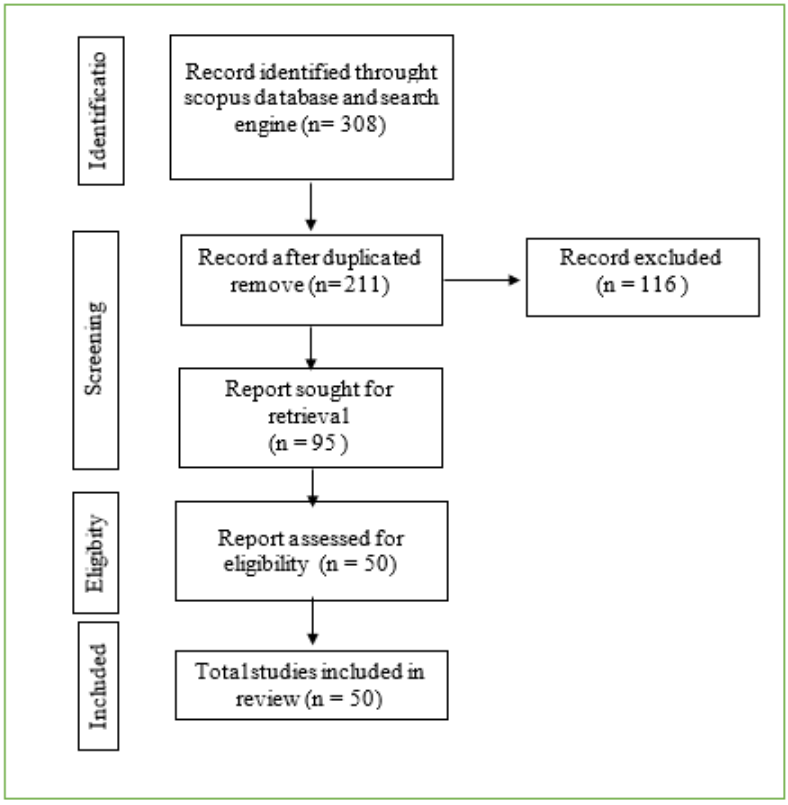

Figure 1. PRISMA Flow Diagram of the Study Selection Process

Article searches were conducted by entering the keywords creative thinking, critical thinking, project-based learning, and science into the Google Scholar, Researchgate, and SINTA pages. Research results based on international journal publications, accredited national journals, and national seminars between 2014 and 2025 were used to select articles for secondary data collection. In conducting literature review research, data is collected and sorted again based on inclusion and exclusion criteria. The criteria include the following: the type of paper is journal and proceeding, range about 2015 until 2024, subject discuss STEM, the object research formal students such as elementary, middle, high school, college levels and teacher. Exclusive criteria include: the type of paper source form website and article, range less than 2015, discuss not STEM and the object research non formal student and special school.

RESULT AND DISCUSSION

The aspects that can be obtained according to the formulation of the problem presented are found after grouping journal articles according to research categories. This is explained in the following table:

Table 1. Classification of Research Articles Based on Research Categories

Country	Level	Method	Discipline	Results
United States of America	Preschool - Secondary School	Mixed Method	STEM	increasing access to research findings for researchers and educators through open-access platforms, and encouraging collaboration between scientists and educational researchers to

Country	Level	Method	Discipline	Results
				deepen knowledge about STEM education (Li, 2014).
Netherlands, Greece and Switzerland	Elementary, Middle, High School	Mixed Method	STEM	Go Lab provides support for teachers in designing effective learning environments and challenges in changing teaching approaches to more inquiry-based ones (de Jong et al., 2014).
Japan	JUNIOR HIGH SCHOOL	mixed method	STEM, Physics	Students' critical thinking scores increased in the STEM learning system (Mutakinati et al., 2018).
Belgium	all level	SLR	STEM, education	Integrated STEM education approaches in 5 theoretical framework (integration of STEM content, problem-centered learning, inquiry-based learning, design-based learning and cooperative learning) (Thibaut et al., 2018).
Vietnamese	Teacher	Qualitative	STEM	Inclusive STEM education can contribute to the achievement of SDG4 which is equitable and quality education for sustainable development and sustainable lifestyles and social justice (Nguyen et al., 2020).
China	JUNIOR HIGH SCHOOL	Case study	STEM, ICT	The implementation of cross-disciplinary activities in schools can improve students' understanding and skills in STEM, as well as encourage collaboration between various disciplines (Leung, 2020).
USA	Junior High School, Senior High School	SLR	STEM	STEM encourages students to excel in multidisciplinary learning especially for practical aspects (Gao et al., 2020).
USA	College	experimental	STEM	Through an examination of students' experiences with RMA at the campus, academic, and peer levels, the current study considers the role of campus racial climate in contributing to representational gaps in STEM professions (Lee et al., 2020).
Türkiye	Secondary school	mixed method	STEM, Physics	STEM has an impact on students' critical thinking skills with the concept of seeking truth and being open-minded, and has a positive impact on students' perceptions of the relationship between STEM

Country	Level	Method	Discipline	Results
				disciplines and real life(Hacioğlu & Gülhan, 2021).
Malaysia	Primary school	experimental	STEM	STEM helps improve students' HOTS through effective learning, with evidence of an increase in students' HOTS scores (Keleman et al., 2021).
Türkiye	SENIOR HIGH SCHOOL	experimental	STEM	STEM has a positive influence on the use and development of skills and increases sensitivity to the environment (Baran et al., 2021).
Indonesia	SENIOR HIGH SCHOOL	experimental	STEM	This learning approach can produce extensive student reflection on the application of STEM-PjBL and the development of critical thinking skills, creativity, motivation, and student engagement in learning (Rahmawati et al., 2021).
USA	College	experimental	STEM	The STEM Network provides a model construct to meet these challenges through its foundation in the Transformational Communities model, use of emergent outcomes to guide Network activities, and use of systems design for organizational change to transform the complex higher education landscape (Santangelo et al., 2021).
China	Teacher	Case study	STEM	This study reveals that three processes (i.e., the process of educational change, the process of creating new or dual professional identities, and the process of generating teacher emotions) can be interrelated and developed together (Jiang et al., 2021).
China	College	mixed method	STEM	STEM helped student develop in problem solving and critical thinking aspect, expecially sustainability competence SDG 4 (Chan & Nagatomo, 2022).
Türkiye	College	experimental	STEM	STEM can improve students' critical thinking skills, especially in solving environmental problems, in this case turbidity in water (Oyewo et al., 2022).
USA	facilitator	Case study	STEM	The facilitator changes roles depending on the STEM module used, be it FLC (Faculty Learning Community) or FOLC (Faculty

Country	Level	Method	Discipline	Results
				Online Learning Community) (Martin et al., 2022).
USA	high school	Case study	STEM, ISE	Participation in authentic research in the context of ISE provides an important opportunity for youth to gain mastery of multiple science skills and practices, which in turn strengthens, and in some cases enhances, participants' interest in scientific research beyond the scope of the program (Habig & Gupta, 2022).
Türkiye	College	Quantitative	STEM	Motivation of female science education students towards STEM fields is different, the results obtained from this study are valuable for the design of possible intervention studies in the future (Dökme et al., 2022).
Australia	College	Case study	STEM	The responses and resilience of STEM academics focused on education appear to depend on the interaction between individual dispositions in the microsystem and the influences of the external exosystem and macrosystem (Ross et al., 2022).
USA	All levels	SLR	STEM	Approaching STEM education and mentoring, we argue for centering intersectionality in the mentoring process as a way to not only fix our HE systems, but also build better and more equitable systems (Nkrumah & Scott, 2022).
Indonesia	students of all levels	Systematic Literature Review	STEM	The implementation of STEM in Indonesia has been running for 6 years where STEM is a project-based learning, based on problems and inquiries so that it can facilitate the formation of critical thinking skills and scientific literacy (Ilma et al., 2023).
Indonesia	students of all levels	Systematic Literature Review	STEM	STEM maximizes understanding and critical and creative thinking capacity (Zulyusri et al., 2023).
Indonesia	JUNIOR HIGH SCHOOL	Systematic Literature Review	STEM	STEM is an effective method in students' critical thinking skills because it can connect personal experiences with the concepts being studied (Wahdah et al., 2023).

Country	Level	Method	Discipline	Results
Portuguese	SENIOR HIGH SCHOOL	experimental	STEM	The STEM approach has a real effect on the development of students' cognitive structures, which strengthens research in STEM education, through a pedagogical approach that allows students to achieve learning objectives (Baptista & Martins, 2023).
China	Student	Systematic Literature Review	STEM	STEM research and higher education development with the presence of AI give rise to competition, crisis and conflict between AI and human intelligence (Nam & Bai, 2023).
Türkiye	Student	experimental	STEM	An untested physics scheme can be applied well through the STEM approach (Erol & O˘ Gur, 2023).
USA	SENIOR HIGH SCHOOL	experimental	STEM	The Lego EV3 robot has a positive impact on STEM learning about Newton's 2nd law (Addido et al., 2023).
Sweden	All levels	SLR	STEM	Integrating individual STEM subjects during teaching, in terms of including disciplinary knowledge and skills, requires specific competencies (Hallström et al., 2023).
Indonesia	students of all levels	Systematic Literature Review	STEM	Literature analysis over the past 10 years shows that STEM can be used at elementary to college levels, the success of STEM is determined by preparation, operational assistance and extracurricular activities that can encourage active learning that focuses on students (Simamora et al., 2024).
Indonesia	Science Teacher	mixed method	STEM	Initial mastery of teaching methods, motivation to achieve targets, and expectations of development programs have a more significant influence on achieving mastery of innovative modification skills of science learning methods (Taufiq et al., 2024).
Kazakhstan	SENIOR HIGH SCHOOL	Systematic Literature Review	STEM, physic	Analysis of STEM teaching systems with various methods such as 3D-based virtual labs helps teachers in physics experiments and minimizes damage to physics

Country	Level	Method	Discipline	Results
				lab equipment (Usembayeva et al., 2024).
Greece	Teacher	Mixed method	STEM	STEM best fits every use case of a concept whether it involves hardware or software (Boltsi et al., 2024).
Nigeria	high school	Systematic Literature Review	STEM	STEM education integrated with sustainibility in high school to support growing demand for professional in renewable energy and green chemistry sector (Chioma Angela Okonkwo et al., 2024).
Qatar	Teacher	quantitative	STEM	Teacher face a barrier in STEM class and take crucial insight to increase student achievement (Sellami et al., 2024).
Indonesia	college	pre-eksperimental	STEM	Mobile simulation (STEM embedded oscilation) improve student thinking skill (Nurita et al., 2024).
Australia	preschool	Systematic Literature Review	STEM	Early chilhood children play everyday STEM to aspire and enggage in STEM-related educational (Kewalramani et al., 2024).
Malaysia	SENIOR HIGH SCHOOL	quasi-ecperimental	STEM	STEM cooperative learning promoting collaboration, critical thinking and active engagement (Mafarja et al., 2024).
Canada	Teacher	mix method	STEM	Bangladeshi STEM teacher's challenges technological knowledge, pedagogical knowledge and content knowledge (Toma et al., 2024).
Canada	all level	SLR	STEM	STEM education have a different approaches and diverse perspective to effective valuable support to the next generation skill (Milner-Bolotin & Martinovic, 2025).
Italy	high school and college	Qualitative	STEM	Stereotypes and biases found in STEM and physic orientation expecialy female participant, so that inclusive and supprtive environment needed (Silva et al., 2025).
USA	all level	SLR	STEM	Lesson study have impact the teacher beliefs and professional community because integrating technologies and online collaboration tools (Karie Brown et al., 2025).

Country	Level	Method	Discipline	Results
UK	elementary	case study	STEM	engineering and technology outreach important for a well-designed evaluation strategy and feedback STEM mechanism (Emembolu et al., 2025).
China	all level	SLR	STEM	STEM trend develop very fast and teacher play a crucial role in the success of STEM education (Chiu et al., 2025).
Indonesia	all level	quasi eksperimental	STEM	Student's skills improved in conceptual mastery, data literacy, and tecnological literacy (Asrizal et al., 2023).
Australia	all level	SLR	STEM	Entrepreneurial STEM enterprise capabilities education to developing life-long learning capabilities (Davis et al., 2025).
China	all level	SLR	STEM	STEM has large effect on cognitive skill, using ekstra teaching and learning strategies (Chen et al., 2025).
China	all level	SLR	STEM	Integrated STEM have different aspect depend on teacher as fasilitator to give student authentic learning experiences (Chiu et al., 2025).
Russia	secondary school	mix nethod	STEM	The CCSGS respresent a successful integration of STEM education in agriculture and use advance technology (Tamayo-Ruíz et al., 2024).
Kazakhstan	teacher	mix nethod	STEM	Formation of STEM competencies essential to provide effectivenes in integrated STEM (Khadisha et al., 2025).

This systematic literature review discuss journal published from 2014-2025 in several country. The finding form analysis 50 journal are presented in graph below, the information divide by trend over the year, country, and subject of STEM education research. A decade ago, the journal which discuss STEM has found and increased every year. Since 2014, writer found 2 paper and the number rise until 2025.

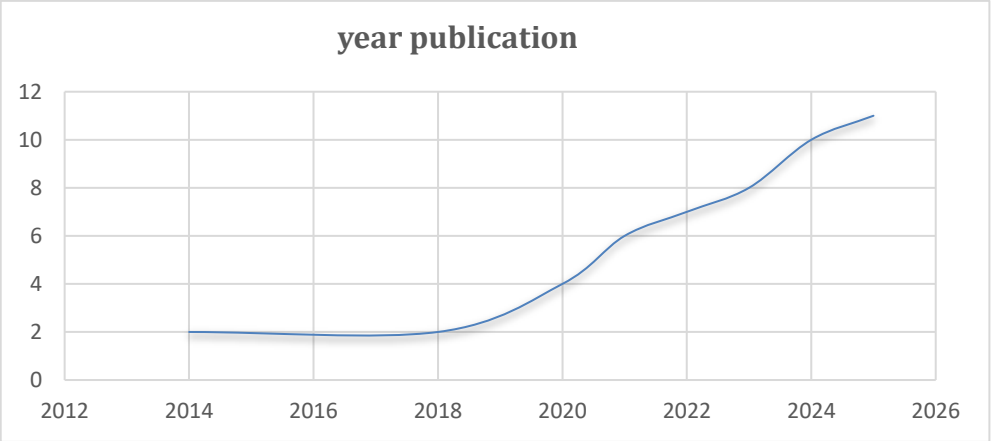

Figure 2. Distribution of Article by Year Published

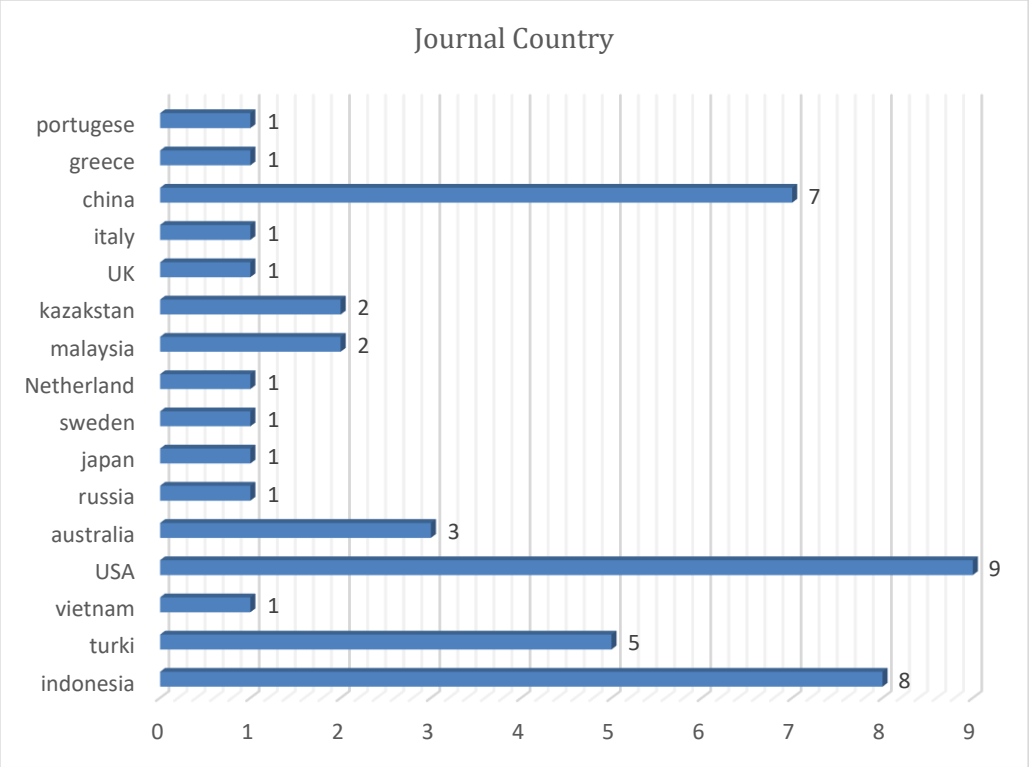

Figure 3. Distribution country of origin articles

Based on finding the research, STEM method has been adopted all over the world. Most of journal publication came from USA and China. Indonesia also used STEM as learning strategies in education, that can be seen reseach education on STEM grow rapidly. Meanwhile other country implementated STEM like Portugese, Greece, Italy, UK, Malaysia, Kazakstan, Netherland, Sweden, Japan, Russia, Australia, Vietnam and Turkey.

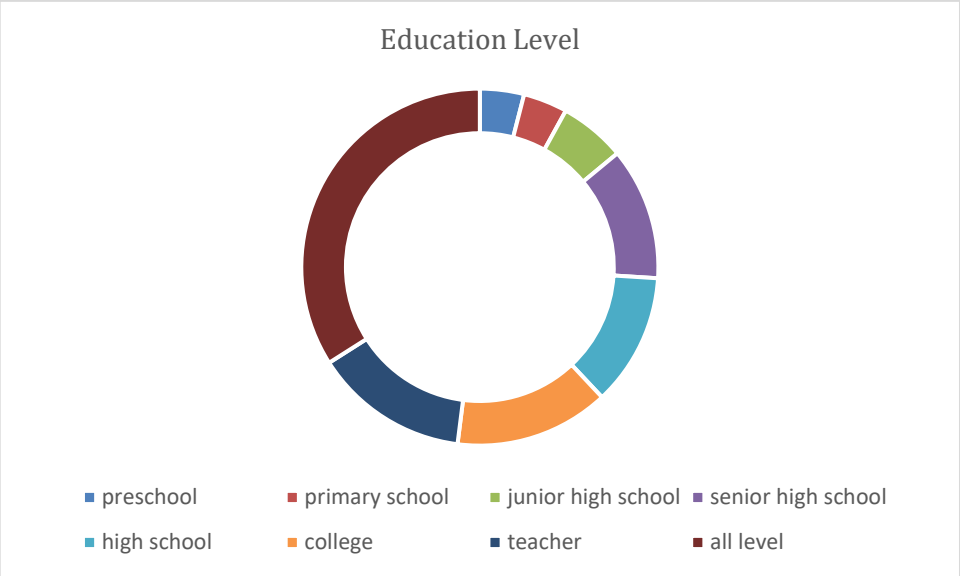

Figure 4. Distribution of STEM education level

STEM is a learning concept that can be used at various levels of education. This is found from various sources of articles that research STEM both at elementary, secondary, tertiary levels and even among educators. The integrated STEM has been widely used with various learning model in different situation in class. Result STEM research show participants developed competence in mastering several of the skills and practices of science (Habig & Gupta, 2022).

Eksperimental learning theory help student build contructive philosophy, integrating new knowledge with existing knowledge. STEM have that point to use LEGO EV robots Newtonian second law concept in formal school (Addido et al., 2023). Visualisation or eksperimental justification in physic is a central teacher problem in class. STEM education offer visualisation difficult physic concept, one of the method is using Arduino (Boltsi et al., 2024). STEM educational system need lowcost and accessible material, Arduino is one of the suitable tool to support STEM method (Erol & O˘ Gur, 2023).

STEM have integration of technology, like computer simulation wich particularly effective in engaging student reinforcing theoretical concept. (Chioma Angela Okonkwo et al., 2024). STEM education also describe pedagogical approach to support student achieve learning goal and develop student cognitive structure (Baptista & Martins, 2023). Teachers play a crucial role in driving these changes. Their professional development not only influences the effectiveness of teaching and learning but also addresses equity concerns, such as inclusivity and diversity. Teacher motivation toward STEM performing STEM activity and successful participant in learning process. But finally, student participant require awareness of STEM education. Investigation found total student motivation toward STEM depend with family income, mother's education level, behavior, personal characteristic and other special qualities (Dökme et al., 2022)

STEM application have several limitation such as material contained in teaching material, integrating concept into STEM, observation aspect and group of student (Asrizal et al., 2023). Data show that teaching material usually have several concept, STEM need material wich promote student literacy as project basis. Different point need integrated succefully to create

good observation. Also in student approach as subject of STEM, each member of group of student hold human literacy section. Human literacy involve critical thinking, creative, collaboration and communication skills (Asrizal et al., 2023). Twenty first century skills most important thing to be concerned in every countries. Concept of knowledge of economy need generation with creatively, critically and contribute innovation. STEM education had positive effect develop critical thinking, mastering technology and increase creativity

CONCLUSION

Ability of student in various grade show increased in critical thinking, problem solving and technology mastery. The role of educator as facilitators hold the important aspect. Skill to make a learning plan is challenge because it determines a STEM project. STEM which is related to solving concrete problem can be answer in global condition.

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