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Exploring the Role of Diagnostic Assessment in Enhancing Student Creativity in STEAM Learning on Environmental Change

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ABSTRACT
STEAM-based education has evolved to integrate science, technology, engineering, art, and mathematics in solving global, complex real-world problems, including environmental issues such as climate change and ecosystem destruction that demand creative, innovative, sustainable solutions. STEAM helps learners combine scientific data with creative design to generate sustainable solutions and foster creative thinking. Cognitive Diagnostic Assessments identify learners' cognitive strengths and weaknesses, allowing targeted interventions to enhance creativity. This study explores the relationship between cognitive diagnostic assessment and students' creativity development based on previous research, reviews scientific literature on diagnostic assessment in STEAM learning on environmental change, finds patterns, trends, and research gaps related to diagnostic assessment in STEAM contexts oriented toward strengthening creative thinking skills, and formulates conceptual and practical recommendations for designing STEAM learning based on diagnostic assessments that encourage creativity. This descriptive qualitative research using the Systematic Literature Review (SLR) approach evaluates Cognitive Diagnostic Assessment to strengthen creativity in STEAM-based environmental change learning, with VOSviewer media for collecting research data from credible sources. The results show research novelty between 2021 and 2024, the relationship between cognitive diagnostic assessment and students' creativity development in STEAM learning, especially on environmental change topics, based on existing literature reviews, enabling comprehensive knowledge learning from various scientific sources as a foundation for developing more effective, innovative learning models or strategies and achieving student learning goals.

Keywords: *Cognitive Diagnostic Assessment; Creative Skills; Environmental Change*; *STEAM.*

INTRODUCTION
One of the terms that is familiar in the world of education is assessment which is a process in an effort to obtain information in decision-making by teachers. According to (Adzkia et al., 2024) Assessment is a process that is taken to obtain information that is used to make decisions related to students, curriculum, programs, and other educational policies, methods or instruments managed by a field, institution, organization or official institution that is organizing certain activities. Diagnostic assessment is an activity used by teachers to first ascertain the characteristics of students such as learning styles, interests, talents, and potentials and formulate a learning plan that is tailored to the characteristics of students (Ayuni et al., 2023)**.** The purpose of diagnostic assessment is to find out the extent of students' understanding of the subject matter and non-cognitive diagnostic assessments aim to collect information related to students' psychological and social-emotional well-being, home learning habits, family conditions, friendship environment, as well as students' learning styles, character, and interests ((Rakhmi et al., 2023). So cognitive diagnostic assessment is a process to obtain information related to students, curriculum, programs, educational policies, and student education methods by teachers such as learning styles, interests, talents and potential of students to find out students' understanding that is tailored to the needs of students.

According to (Antika et al., 2023) explained that diagnostic assessments are divided into two with their respective objectives, including cognitive diagnostic assessments and non- cognitive diagnostic assessments. Cognitive diagnostic assessments can be applied using tests, quizzes, projects or

assignments, portfolios, teacher questions and answers with students or observations. Cognitive diagnostic assessments in the form of tests can be implemented using HOTS questions *(Higher Order Thinking Skills*) which can be given to students through pre-test and post-test. According to (Kadir et al., 2022) Creative thinking is a mental activity that a person uses to formulate ideas and develop new ideas fluently, and flexibly.). Creative thinking skills are skills to solve problems that must be possessed by students. Knowledge gaps affect students' creativity (Edgecomb et al., 2024). According to (Utomo Aji et al., 2024) With the ability to think creatively, students can find a wide variety of ideas and problem-solving solutions. The importance of creative thinking for students is that it can stimulate further thinking skills to solve a problem in each learning activity applied in the curriculum to support the cognitive realm of students which will make it easier for students to produce new ideas and innovative solutions in solving problems with original thoughts. According to (Mukaromah & Inayah, 2025) There are 4 levels of creative thinking skills, namely level 4 or very creative if students are able to meet the indicators of fluency, flexibility, originality, and elaboration. So diagnostic assessments are divided into two based on their objectives, namely cognitive diagnostic assessments and non-cognitive diagnostic assessments. Cognitive diagnostic assessments can be implemented through tests, quizzes, projects or assignments, portfolios, teacher Q&A with students or observation using HOTS questions *(Higher Order Thinking Skills*).

The environment according to (Yusuf et al., 2024) is a continuous unity between space and all objects, forces, conditions and living things and all their behaviors that can affect nature. According to (Peters et al., 2024) Environmental change manifests itself through changes in ecosystems, landscapes, biodiversity, and natural resources, as well as climate change-related impacts such as rising temperatures, changes in precipitation patterns, and increasing frequency of extreme weather events. The material on environmental change contained in the field of biology study discusses the life of living things in their environment. This material can train students' critical thinking skills if implemented with the right learning tools (Dewi & Purnomo, 2023). According to (Qoyyimah et al., 2023) Science subjects are the essence of science which contains, theories, concepts, laws and principles derived from creative thinking through discovery, observation, techniques and truths that can be seen from the curiosity of seeing natural events. The material on environmental change has characteristics related to the environment in daily life which can be called contextual problems where students are faced with biological problems that occur in the surrounding environment and students can determine the right solutions or solutions to solve these problems. So the environmental change material in high school science learning includes living things and their environment such as their definition, causes and impacts on life, as well as formulating ideas for solving environmental changes that occur in the surrounding environment through changes in ecosystems, landscapes, biodiversity, and natural resources, as well as impacts related to climate change such as rising temperatures, changes in precipitation patterns, and increasing the frequency of extreme weather events by natural factors, such as climate change and geological activities, or it can be due to human intervention, such as industrial pollution and deforestation to train students' creative thinking skills in learning.

The approach that can be integrated in the assessment process is the STEAM (Science, Technology, Engineering, Art and Mathematics) approach which is an effort to combine several disciplines, technology, engineering, art and mathematics into one unit or lesson based on the relationship between other subjects and real-world problems by helping students think creatively. According to (Nanang Mantulangi et al., 2025) Education in the 21st century is an education that is able to develop the potential of students so that they can face and solve the life problems they face. Education in the 21st century does not only depend on information transfer, but also on the interaction process that takes place in the classroom, because direct learning in the classroom helps students develop learning process skills more effectively. STEAM is a multidisciplinary learning approach that is integrated to foster and enhance the realization of the goals of the independent learning curriculum that has been designed in accordance with 21st century skills (Iaskyana et al., 2022). STEAM is the development of learning methods that can help students to be able to explore ideas and ideas and solve problems through students' proficiency related to their surrounding environment and technical (Aurelia Tari Fortuna & Yanda Bara Kusuma, 2023). So STEAM is one of the approaches that can be integrated in learning assessments that need to be developed, especially in the 21st century to grow and improve the realization of the goals of the independent learning curriculum that has been designed in accordance with 21st century skills. The STEAM approach is a multidisciplinary learning approach that can help students to be able to explore ideas and ideas and solve problems through students' skills related to their

surroundings.

The main challenge in the development of diagnostic assessment instruments is the lack of teachers' understanding of basic concepts, theories, and practices, as well as adjustments to changes in curriculum assessment procedures. Teachers often misunderstand the purpose (equalized by pre-test), so that student information is not optimally utilized. Limited time, resources, and training make assessments less valid, especially in biology learning, so their implementation is not efficient and effective for learning. The lack of emphasis on creative thinking skills in the curriculum, so that learners only receive knowledge from teachers without active involvement, makes creative abilities inferior to critical. The main challenge is to change the paradigm from teacher-centered learning to student-centered, with innovative methods such as problem-based learning to develop the 6Cs, as well as improving teacher competence so that learning can be *student-centered.* Students experience difficulties in analyzing, formulating, and solving problems related to environmental issues such as climate change, deforestation, pollution, and resource exploitation. This is due to the lack of concern of students in protecting the environment. Environmental change materials are expected to increase students' understanding of the environment and increase their awareness to protect the environment. STEAM learning barriers are the lack of pedagogic support and knowledge, technical challenges, time, access to content, facilities, and human resources who understand STEAM concepts. Careful preparation and long time are also a challenge.

This study aims to explore the relationship between cognitive diagnostic assessment and the development of students' creativity, based on findings from various previous studies. Identify and review the scientific literature that discusses the application of diagnostic assessments in STEAM learning, particularly on the topic of environmental change. To find patterns, trends, and research gaps related to diagnostic assessment in the context of STEAM oriented to strengthening creative thinking skills.

METHOD

This study is designed as a descriptive qualitative study that integrates the Systematic Literature Review (SLR) approach to build a theoretical foundation, data collected systematically by collecting, measuring, and analyzing research data information. This study aims to identify how cognitive diagnostic assessments can be applied to increase students' creativity in the context of environmental learning that combines elements of Science, Technology, Engineering, Arts, and Mathematics (STEAM). The SLR approach begins by formulating clear research questions, such as how cognitive diagnostic assessments contribute to the development of creative skills in STEAM learning related to environmental change, then a literature search is carried out systematically through databases such as Google Scholar, Scopus, and Indonesian education journals, using specific keywords such as "cognitive diagnostic assessment", "creative skills", "STEAM", and "learning environmental change". Selected articles from 2021 to the present that are relevant to avoid bias. After collecting articles, data are extracted to identify key themes, such as effective cognitive assessment models or the impact of STEAM on creativity, which are then synthesized through thematic analysis to form a conceptual framework that supports primary research.

For the primary part, this study uses a phenomenological approach to understand the distribution of key data publications from year to year, with SLR as the basis for comparing the urgency of the novelty of research publications. Data collection is carried out by systematically presenting or displaying data, reducing the amount of data without reducing important information before finally drawing conclusions on the data and verification.

Data analysis is carried out through a thematic approach, starting with a complete transcription of the lithoreature study conducted, then processed inductively based on patterns emerging from the primary data, while integrating deductive elements from the SLR theme for confirmation or contrast and then identified and developed into a narrative. Software such as VOSviewer is used to organize the data and visualize the relationships between supporting keyword themes, allowing for a final synthesis that compares the novelty of the research data.

In terms of ethics, this study adheres to research ethical principles such as honesty and transparency in explaining data openness, credibility and validity of data sources, avoidance of plagiarism, objectivity in data analysis, and relevance and context of data. Key limitations include small sample sizes, which limit the generalization of results to a wider population, as well as potential bias in SLR if UNWAHA's local literature is limited, so this study focuses more on depth of insight than statistical representation. Overall, the method is designed to run for six to nine months, from SLR

preparation to final report preparation, with adjustments based on developments in the field to ensure the relevance and authenticity of the findings.

RESULT AND DISCUSSION

This study provides an overview of the direction and focus of research based on the frequency and relevance of keywords, visualizes the relationships between keywords in scientific publications, identifies trends and *thematic clusters and* research gaps from 2021 to 2024 related to cognitive diagnostic assessments, students' creative skills, STEAM and environmental change using VOSviewer as a medium in the approach Systematic Literature Review (SLR).

This study aims to provide a comprehensive overview of the direction and focus of scientific studies related to cognitive diagnostic assessment, students' creative skills, STEAM learning, and environmental change issues. Using the Systematic Literature Review (SLR) approach, this study compiled and analyzed various scientific publications published between 2021 and 2024. Through this process, the researcher identified the frequency of occurrence of keywords and their relationship with each other in the context of STEAM-based education.

As a visualization tool, VOSviewer software is used to map relationships between keywords found in the literature. This visualization displays a thematic network formed from the co-existence of keywords, showing clusters that represent the dominant themes in the research, such as the role of teachers, learning strategies, the impact of assessments, and the development of students' creativity. Each cluster shows the direction of development of ongoing research topics and trends, as well as revealing research gaps that have not been explored much.

With this approach, the research not only presents bibliometric data, but also compiles a synthesis of knowledge that can be the basis for the development of more innovative STEAM learning models. The results of this research are expected to be able to make theoretical and practical contributions in designing effective diagnostic assessments to increase students' creativity in facing the challenges of environmental change.

Result

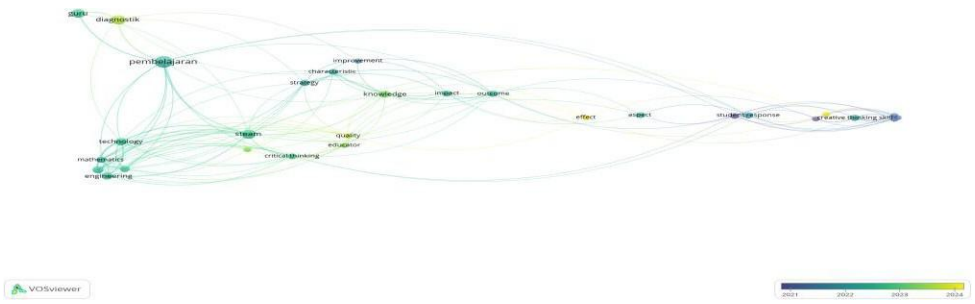

Figure 1. Distribution of Publications by Keywords

Figure 1 is a visualization of a bibliometric network that shows the relationships between keywords in academic publications to help understand research trends and the interconnectedness of topics to each other. The results of the visualization data explain that there is a change in the direction of research topics from 2021 to 2024, this can be used to identify research trends that are often discussed in that year so that they can be used to determine the next direction of research and conduct research that has not been explored much. Where each node/dot represents each keyword from the publication, the connecting line shows the relationship between two keywords in one or more documents and the color mindicates the average year of publication of the document related to that keyword. Green represents the average year of publication in 2021, blue represents the average publication between 2022 and 2023, and yellow represents the average publication in 2024 or the most recent. The keywords that are interconnected and the most prominent are learning and teachers which is the central topic in research in the field of education related to diagnostics in the form of cognitive diagnostic assessments carried out by teachers on students, then there is STEAM as a multidisciplinary approach which is a combination of Science, Technology, Engineering, Arts, Mathematics which is associated with creative thinking and creative thinking skills that are indispensable Especially in the 21st century so that strategies, knowledge,

impacts, outcomes, effects and aspects of learning emerge as a study of learning effectiveness that leads to students' learning responses.

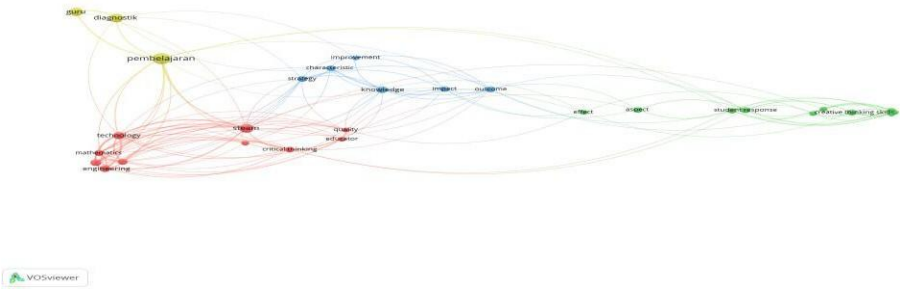

Figure 2. Research Keywords

Figure 2 explains the structure of the visualization of nodes/points that represent each keyword which is differentiated based on the size of the point. The larger the point in the keyword, the more often the keyword is used in the research. The line between the dots indicates the co-existence relationship of two keywords often appears together in research. And colors indicate thematic clusters that group keywords that are thematically interrelated. The yellow cluster shows the main keywords in the form of learning, teachers and diagnostics as the learning process and the role of teachers. The red cluster in the form of steam, technology, mathematics, engineering, critical thinking is the core of STEAM and critical thinking skills. Blue is a learning strategy and impact in the form of strategy, characteristic, improvement, knowledge, impact, outcome, quality, educator. As well as green clister with effects, aspects, student response, creative thinking skills showing student responses and creative skill development. Learning and teachers are at the center of the yellow cluster which indicates that the role of teachers is very important in the context of STEAM. The red cluster shows that STEAM components such as technology and mathematics are closely related to the development of critical thinking. The blue cluster emphasizes learning strategies and outcomes, such as quality and impact on learners. The green cluster leads to learners' responses and creative thinking skills, which are the focus of recent research.

Discussion

Figure 1 explains the distribution of research publications that discuss gap research between 2021 and 2024. At the node/point, teachers have a relationship with learning and STEAM that is studied between 2022 while the relationship between teachers and diagnostics is studied in 2023. The diagnostic nodes that were studied on average in 2023 were related to previous research such as teachers, learning, technology, strategies, and characteristics ranging from 2022 to, as well as diagnostics related to the improvements studied in 2021. Learning, which is the largest node/point, shows that the frequent use of keywords in learning research has a relationship with validity in 2021, and in 2022 learning is often associated with student responses, research between learning that has a relationship with teachers, STEAM in terms of science, technology, engineering, art and mathematics, critical thinking, and the average outcomes of research conducted in 2022 to 2023, and the latest research has been carried out on learning with knowledge and diagnostics in 2024.

In 2022, on average, research was conducted that discussed technology with strategies, characteristics, learning, STEAM (science, engineering, art and mathematics), critical thinking, and in 2023 the end of technology has a novelty of research related to diagnostics, literature studies, and educators, until in 2024 the relationship between technology research and quality will be the latest. Mathematics has a research relationship with learning, STEAM (science, technology, engineering, and art), strategy and critical thinking in 2022, and in 2023 mathematics is linked to the study of literature and educators, as well as the relationship of mathematics with educators in 2024. Science in 2022 is associated with learning, strategy, STEAM (technology, engineering, art and mathematics) and critical thinking, and in 2023 science is associated with educators and literature studies until in 2024 science is associated with quality. Engineering/engineering is on average associated with STEAM (science, technology, art and mathematics), strategy and learning in 2022, literature studies and educators in 2023 and in 2024 are associated with quality. Art/art in 2022 is on average associated with STEAM (science, technology, engineering, and mathematics), learning, critical thinking, and strategy, in 2023 art is linked to literature studies and educators, and in 2024 art is associated with quality.

STEAM has been done a lot so that there are many links with other fields, especially science, technology, engineering, art and mathematics, teachers, learning, strategy, critical thinking, and outcomes carried out in 2022, in 2023 STEAM is associated with the study of literature, educators and knowledge, and in 2024 STEAM is associated with the effects and shortcomings that are the latest research. Literature studies that have been conducted extensively in 2023 are also related to previous research in 2022 such as characteristics, STEAM (science, technology, engineering, art and mathematics) and creative thinking, in 2023 literature studies are linked to educators and knowledge, as well as the relationship between literature studies and the quality of being researched in 2024. In 2021 critical thinking is associated with validity, and in 2022 the average critical thinking is associated with student responses, learning, STEAM (science, technology, engineering, art and mathematics) and outcomes, and in 2024 critical thinking is associated with educators and literature studies. Educators who are widely researched in 2023 are associated with previous researchers in 2022 such as STEAM (science, technology, engineering, art and mathematics), critical thinking, outcomes, impact and aspects, in 2023 educators are associated with knowledge and literature studies, and quality is associated with educators in 2024. Quality which is the latest topic in 2024 is related to previous research such as in 2022 it has a relationship with science, technology, engineering, art and mathematics, strategy, and impact, in 2023 quality has a relationship with educators and knowledge, while in 2024 quality has a relationship with the effect that is the latest research.

Strategy is related to improvment in 2021, STEAM (science, technology, engineering, art and mathematics), characteristics, impact and outcomes in 2022, knowledge and diagnostics in 2023 and in 2024 strategy is related to quality. Characteristics have a relationship with improvment in 2021, in 2022 characteristics have a relationship with technology, strategy, impact and income, while in 2023 characteristics have a relationship with diagnostics, literature studies and knowledge. Improvment, which is a field of study that is widely researched in 2022, is related to strategies, characteristics, impacts, and outcomes in 2022 as well as related to diagnostics and knowledge in 2023. Knowledge, which is a field of study that is widely researched in 2023, has a relationship with previous research such as improvment in 2021, learning, STEAM, strategies, characteristics, impacts, and outcomes in 2022, and in 20223 knowledge is related to literature studies and educators, and in 2024 knowledge is related to the quality and effects that are the latest research. Impact is related to improvment in 2021, strategies, characteristics, outcomes and aspects in 2022, educators and knowledge in 2023 and in 2024 related to quality and effect. Outcomes are related to previous research, namely on improvisation and validity, and the average research in 2022 is related to learning, STEAM, critical thinking, strategies, characteristics, impacts, aspects and student responses, in 2023 related to educators and knowledge, and in 2024 it is related to shortcomings.

The effect, which is a study of research topics in 2024, is related to previous research such as validity in 2021, creative thinking, STEAM and impact in 2022, in 2023 related to knowledge and in 2024 related to quality. Aspects related to validity in 2021, impact, outcomes and student responses in 2022, and relationships with educators in 2023. Student responses are related to validity, students' creative thinking skills, flexibility, fluency and indicators in 2021, in 2022 they are related to creative thinking skills, and in 2023 they are related to learning, critical thinking, aspects, outcomes, and the relationship between students' responses and shortcomings in 2024. Validity as a research topic in 2021 has a relationship with students' creative thinking skills, flexibility, fluency, and indicators in 2021 itself, in the latest research validity has a relationship with creative thinking skills, student response, critical thinking, learning, aspects, and outcomes. Students' creative thinking skills have a relationship with validity, flexibility, fluency and indicators in 2021, student responses and creative thinking skills in 2022 and 2024 have a relationship with effects. Effective thinking skills are related to students' creative thinking skills, flexibility, fluency, indicators, and validity in 2021, students' responses in 2022, and in 2024 related to effects and shortcomings. Disadvantages as a topic of discussion for research in 2024 are related to previous research such as flexibility and fluency in 2021, student responses and creative thinking skills in 2022, and 2023 related to STEAM and outcomes. Flexibility is related to fluency, indicators, students' creative thinking skills, and validity in 2021, and in 2022 it is related to students' responses and creative thinking skills, as well as related to shortcomings in 2024. Indicators relate to flexibility, fluency, students' creative thinking skills, and validity in 2021, creative thinking skills in 2022, and deficiencies in 2024. Fluency is related to students' flexibility, indicators, creative thinking skills, and validity in 2021, creative thinking skills and learners' responses in 2022 and deficiencies in 2023.

Figure 2 is the result of a bibliometric analysis that aims to identify and map the thematic

relationships between keywords in the academic literature. Using VOSviewer, a specialized software for building and visualizing bibliometric networks, we can see how concepts in STEAM education are interconnected, form thematic clusters, and indicate the direction of research development. The visualization is useful for finding emerging research trends, identifying research gaps, developing research agendas or curriculum development, and understanding the interconnections between concepts in education. Each node/dot represents the keywords used in an article or academic document. The larger the size of the node, the more often the keyword appears in the literature. edge/(connecting line indicates the co-existence relationship between two keywords, i.e. how often they appear together in a single document, color marks thematic clusters, i.e. groups of keywords that have semantic relevance and often appear together, the positions of the interrelated keywords will be closer to each other, forming a dense visual group. The visualization provides a comprehensive overview of STEAM research in education, with a focus on the integration of disciplines, the role of teachers and learning strategies, student responses and creativity development and diagnostic evaluation and assessment. This can

Practical implications are used to develop a STEAM-based curriculum, as a basis for teacher training in a transdisciplinary approach, helping researchers design advanced studies based on clusters that have not been explored much.

The red cluster contains the core keywords of learning, diagnostics and teachers explaining the local and diagnostic contexts. This cluster leads to an evaluative approach, where teachers conduct formative and diagnostic assessments to understand students' learning needs. The red cluster contains the core keywords of STEAM and the role of educators with the keywords STEAM, technology, mathematics, science, engineering, art, literature studies, critical thinking, quality, and educators. The red cluster is at the heart of the STEAM approach, which combines five disciplines to create holistic and contextual learning. Keywords such as *critical thinking* and *educator* indicate that the main focus is not only on content, but also on the development of higher-level thinking skills and the role of teachers as facilitators of transdisciplinary learning. The blue cluster shows the learning strategy and its impact on learning. This cluster has the keywords improvment, characteristics, strategy, knowledge, impact, and outcome. This cluster focuses on pedagogical approaches and learning outcomes. Keywords such as *strategy* and *impact* show that the research in this cluster explores how STEAM learning strategies affect students' knowledge and skills. In the green cluster, it means student response and creativity. The green cluster has keywords in the form of effects, aspects, validity, student response, regression, students' creative thinking ability, creative thinking ability, flexibility, fluency and indicators. This cluster highlights students' reactions to STEAM learning, as well as how this approach encourages the development of creativity. Keywords such as *student response* and *creative thinking skills* show that STEAM not only increases knowledge, but also encourages the expression of ideas and innovative solutions.

CONCLUSION

From the data above, it can be concluded that there is a novelty of research from 2021 to 2024. In 2021 the research focuses on the validity, improvement, and creative thinking of students, in 2022 it focuses and is active in STEAM research and learning, in 2023 it is emphasized on diagnostics, educators, knowledge, and literature studies, and in 2024 the main focus is on new topics in the form of quality, effects, and shortcomings in research. The results of the bibliometric analysis used VOSviewer to map the thematic relationships between keywords in the STEAM educational literature. This visualization displays thematic clusters formed from the interconnectedness between concepts, such as the integration of disciplines, the role of teachers, learning strategies, student responses, creativity, and diagnostic evaluation and assessment. Each node represents a keyword, with the size indicating the frequency of occurrence, and the border indicating how often the keywords appear together. Colors distinguish thematic clusters, and positions between keywords reflect semantic proximity. The yellow cluster refers to the local and diagnostic context, the red cluster indicates the core of STEAM and the role of educators, the blue cluster indicates learning strategies and their impacts, and the green cluster indicates learners' responses and creativity.

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