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Development of multiliteracy assessment with the STEAM approach to enhance 4C skills in geometry learning

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Abstract

The 4C skills (communication, collaboration, creativity, critical thinking) represent essential competencies for 21st-century students. Multiliteracy contexts play a crucial role in supporting learning, while assessment contributes significantly to achieving educational objectives. However, Indonesian students' PISA results remain very low, particularly in understanding assessments within multiliteracy contexts. Multiliteracy assessment utilizing a STEAM approach offers a solution for developing students' 4C skills in geometry learning through project-based activities. Therefore, this study aims to create an innovative multiliteracy assessment, MASTER-4C, to enhance the development of 4C skills. This research employs an R&D methodology based on the ADDIE model. Participants included six expert validators, two teachers, and 32 eighth-grade students. Results demonstrate that MASTER-4C is a valid multiliteracy learning assessment. Student and teacher responses reached 91.5% and 87%, respectively, categorizing it as highly practical. The activity-based N-Gain scores for communication, collaboration, creativity, and critical thinking skills were 0.62, 0.62, 0.63, and 0.45, respectively. These scores were classified as moderate improvement, with MASTER-4C achieving an 87.5% success rate in the implementation of geometry learning. These findings suggest that MASTER-4C is a functional and valid multiliteracy assessment that effectively supports students' 4C skill development. MASTER-4C shows promise in geometry learning, though broader applicability needs further study.

Keywords:
Development research, Multiliteracy assessment, STEAM approach, 4C

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1. INTRODUCTION

In the 21st century, technology and information play significant roles across various aspects of life, including education, where learning is required to go beyond mere knowledge transfer (Thornhill-Miller et al., 2023). This is marked by the transition from an industrial society to a knowledge-based society. The 21st century has shifted education toward a knowledge-driven society, requiring students to master 4C skills: critical thinking, creativity, collaboration, and communication, to engage with complex learning tasks and real-world challenges effectively (Kain et al., 2024). Thus, superior human resources are a necessity for facing the challenges of this century. The rapid development of science and technology demands improvements in educational quality. After passing through industrial revolution phases 1.0, 2.0, and 3.0, we are now in the era of industrial revolution 4.0, characterized by extremely rapid advances in science and knowledge (Falloon, 2024; Yin et al., 2023).

Learning skills in the 21st century have become essential aspects that need to be provided to students (Bray et al., 2023; Herlinawati et al., 2024). The targeted competencies extend beyond cognitive abilities to include essential workplace competencies such as collaboration, communication, problem-solving, and the effective use of digital tools, which collectively prepare students to participate in an increasingly global and technologically mediated environment. Current educational systems face increasing pressure to equip students with competencies that enable them to adapt to rapid technological change and international competition, particularly within school-based learning contexts (Rapti et al., 2025). In the learning process, students are required to achieve a better balance among attitudes, skills, and knowledge than before (Kain et al., 2024). Thus, learning outcomes are expected to foster the emergence of more productive, creative, innovative, and effective generations by integrating the strengthening of these three domains.

Twenty-first-century learning emphasizes character formation and literacy while systematically embedding the 4C skills: critical thinking, collaboration, communication, and creativity through pedagogical approaches such as problem-based learning, inquiry, and collaborative tasks that require students to generate, evaluate, and communicate ideas in authentic contexts (Krumm et al., 2016; Thornhill-Miller et al., 2023). These skills are the main components for students to face increasingly fierce global competition, requiring meaningful learning. Prior studies show that 4C competencies contribute to students’ social participation and knowledge construction, both individually and collectively (Humble et al., 2018; Sk & Halder, 2020). In the context of this study, these findings align with classroom observations indicating that students who engaged in 4C-oriented tasks demonstrated more effective collaboration and more transparent communication during group work. Furthermore, consistent (Kurniawan, 2021; Sk & Halder, 2020), the findings indicate that structured interaction enhances students’ critical and creative problem-solving, confirming that 4C skills improve learning quality. However, existing studies have not yet examined how 4C skills can be assessed in multiliteracy-based STEAM learning using technology-supported assessment models. Therefore, this study addresses this gap by developing and validating an integrated multiliteracy assessment to strengthen students’ 4C skills.

Technological development has significantly changed educational paradigms. The development of technology is changing the educational paradigm by making learning more digital, flexible, and personalized. Learning is no longer bound by space and time, allowing students to study anywhere and according to their individual needs. The teacher’s role shifts to that of a facilitator, while the curriculum emphasizes digital literacy and 21st-century competencies. Technology also increases efficiency through digital-based assessment and administration, although it still requires adequate infrastructure and digital literacy support (Rapti et al., 2025). It highlights that students today are expected to acquire not only subject-matter knowledge but also essential 4C skills. In this study, we operationally define academic competencies as the interconnected body of disciplinary knowledge, cognitive strategies, and communication abilities that support meaningful learning performance. Within this framework, the 4C skills are conceptualized as embedded competencies that enhance students' ability to interpret, construct, and apply knowledge, thereby forming an inseparable part of the academic competency structure. These four skills are key to navigating the complexity of work, social dynamics, and rapid technological advances. The Partnership for 21st Century Learning, as shown in Figure 1, emphasizes that integrating 4C into curricula is no longer an option but a necessity in modern education (Thornhill-Miller et al., 2023). However, the implementation of 4C skills in learning remains partial and unstructured, and has not become the primary focus in designing teaching materials and assessments (Álvarez-Huerta et al., 2022; Andersen & Rustad, 2022). Creativity and critical thinking are complementary abilities in meaningful learning processes. Creativity allows students to explore ideas, solutions, and new perspectives, while critical thinking trains students to evaluate information, connect various concepts, and make logical and reflective decisions.

However, the core problem in classroom learning is not simply the preference for a single correct answer, but the limited quality of learning tasks that fail to stimulate reflective and higher-order thinking. When problems are overly procedural and closed-ended, students have minimal opportunity to reason, evaluate, and reflect on processes that are essential for cultivating 4C competencies. From both didactic and pedagogical perspectives, this underdevelopment often stems from instructional practices that emphasize content transmission, restrict inquiry, and provide little space for open-ended exploration. Clarifying these factors is essential to strengthen the theoretical basis of this study and to justify the need for learning approaches that more effectively foster reflective thinking and 4C skills. Research by Thornhill-Miller et al. (2023) shows that learning that does not provide space for reflective thinking tends to limit students' ability to analyze and solve problems innovatively.

Meanwhile, collaboration and communication skills are essential for developing interpersonal skills and teamwork. In the real world, success is not only determined by individual abilities but also by how well someone can work with others, convey ideas clearly, listen actively, and resolve conflicts constructively (Jaakma & Kiviluoma, 2019; Li et al., 2022). However, Indonesian secondary education remains dominated by teacher-centered instruction and individual assessments, resulting in limited use of collaborative learning. Consequently, students have fewer opportunities for shared meaning-making and joint knowledge construction. Clarifying this context is essential for positioning the study and for explaining why interaction-based competencies remain underdeveloped. In current instructional practices, assessment remains predominantly focused on content mastery and has not yet effectively measured or supported critical thinking, creativity, collaboration, and communication in a comprehensive manner. This gap indicates that 4C skills are still not optimally facilitated within the learning process. Therefore, the development of learning assessments specifically designed to support and evaluate 4C competencies in a balanced, sustainable, and contextual way is an urgent necessity.

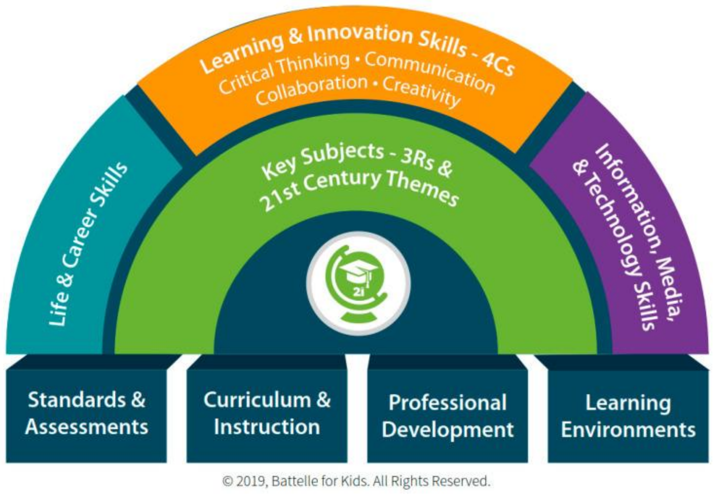

Figure 1. The P21 framework for 21st-century learning
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Assessment plays an important role that must be considered by teachers during the learning process (Kain et al., 2024; Thornhill-Miller et al., 2023). Assessments conducted by teachers serve as benchmarks for the success of learning processes that align with educational standards. Assessment principles include objectivity, systematic approach, comprehensiveness, accountability, and validity (Lüdke et al., 2023; Summak et al., 2010). Assessment is the process of collecting and processing information and evaluating student learning achievement. The assessment process is an essential activity in learning. Assessment becomes constructive feedback for both teachers and students. Instrument quality plays an important role and directly influences the accuracy of student learning outcomes (Barta et al., 2022; Normore et al., 2024; Wang, 2024).

However, criticisms of traditional assessments show that they often fail to reflect the diverse and contemporary ways students learn. This gap calls for alternative perspectives, with multiliteracy offering a theoretically grounded response to the demands of an increasingly digital and multicultural learning environment (Castellano-Sanz & Reyes-Torres, 2024). Multiliteracy encompasses not only conventional reading and writing abilities but also digital, visual, numerical, scientific, and cultural literacies (Usanova et al., 2024). In 21st-century education contexts, multiliteracy provides a strong foundation for developing student creativity, as it enables students to express ideas through various media and symbols. When students are given opportunities to create through text, images, videos, infographics, or digital simulations, they are encouraged to think imaginatively, explore ideas, and produce original works (Amgott, 2023).

Beyond creative expression, multiliteracy also supports the development of critical thinking. Students are invited to analyze messages from various sources and formats, assess information reliability, and understand the social and cultural contexts behind every text or media (Beltrán-Palanques, 2024). Thus, multiliteracy fosters reflective awareness and evaluative capabilities that are essential in facing information floods in the digital era. The ability to read critically, compare perspectives, and draw logical conclusions is part of deep multiliteracy, which is closely related to higher-order thinking skills (Asman et al., 2022).

Furthermore, multiliteracy pedagogies position knowledge construction as a socially mediated process, providing a theoretical basis for improved collaboration and communication. By engaging students in shared meaning-making and interactive learning exchanges, these approaches foster dialogue and co-constructed understanding aligned with socio-constructivist perspectives on collaborative learning. Through project-based and media activities, students learn to convey their ideas clearly to others, using various modes of representation. Students are also trained to work together in designing multiliteracy products, discussing across different viewpoints, and building shared understanding (Karkar Esperat & Stickley, 2024; Usanova et al., 2024). Multiliteracy provides students with space to convey messages in forms suitable to audiences and contexts while training adaptive and collaborative communication skills. Thus, multiliteracy not only reinforces academic competencies but also provides a strategic basis for the development of integrative 4C skills. Empirical evidence shows that multiliteracy-oriented activities such as multiliteracy text production, digital storytelling, collaborative media-based inquiry, and cross-cultural analysis significantly enhance students' critical thinking, creativity, communication, and collaboration. Reported across diverse educational settings, these findings collectively affirm multiliteracy as an empirically grounded approach for cultivating essential 21st-century competencies (Amgott, 2023; Asman et al., 2022).

Although multiliteracy offers strong pedagogical potential, its implementation in classrooms is often constrained by teachers' limited capacity to design multiliteracy tasks, varying levels of digital competence, and insufficient technological support. These challenges are compounded by rigid curricula and assessment systems that continue to prioritize traditional literacy skills, leaving limited space for collaborative and higher-order learning (Karkar Esperat & Stickley, 2024; Thornhill-Miller et al., 2023). The STEAM framework provides a project-based, cross-disciplinary approach that fosters multiliteracy meaning-making, creativity, and collaborative problem-solving, supporting both learning and assessment while effectively operationalizing multiliteracy in classrooms. STEAM emphasizes the importance of holistic, project-based, cross-disciplinary learning that encourages exploration and real problem-solving (Yulianti et al., 2024). This approach aligns with multiliteracy principles because both prioritize learning through diverse forms of representation and communication. Through its integration of inquiry, technology, design, arts, and mathematics, STEAM requires students to work with multiliteracy information, thereby strengthening key multiliteracy skills such as digital navigation, visual-textual synthesis, collaboration, and cross-media communication (Hsu et al., 2023). In this way, STEAM provides an interdisciplinary structure where multiliteracy meaning-making is central to learning (Chappell et al., 2025). Through STEAM, students can develop literacy in various forms, from scientific experiments and data analysis to technology design and visual and digital presentations, enabling them to learn more meaningfully and relevantly to real life (Trina et al., 2025). Geometry tasks integrated into a STEAM framework have been shown to enhance spatial reasoning and mathematical creativity by engaging students in meaningful design processes rather than mere rote computation (Pramasdyahsari et al., 2025).

Although multiliteracy and STEAM both emphasize inquiry, creativity, and collaborative problem-solving, their alignment must be operationalized rather than assumed.

Recent empirical studies demonstrate that STEAM-based, project- or PjBL-oriented learning environments effectively support the development of 21st-century competencies (critical thinking, creativity, communication, collaboration) by integrating multiliteracy and cross-disciplinary tasks (Hidayanthi et al., 2024; Irdalisa et al., 2024). In practice, this requires thoughtfully designed teaching materials that scaffold cross-disciplinary inquiry, digital literacies, collaborative tasks, and real-world problem solving, thereby translating the conceptual synergy between multiliteracy and STEAM into concrete, skill-oriented learning experiences (Hidayanthi et al., 2024; Maulina et al., 2024).

However, despite their conceptual synergy, the integration of multiliteracy and STEAM is not yet fully realized in classroom practices. Many existing instructional materials still emphasize disciplinary content rather than facilitating digital literacy, multimodal communication, and collaborative problem-solving needed for 21st-century learning. Thus, to operationalize the alignment between multiliteracy and STEAM, teaching materials must be designed to explicitly scaffold cross-disciplinary inquiry, contextual learning activities, and skill-oriented performance tasks that reflect authentic real-world challenges (Asman et al., 2022; Lim et al., 2024). This is where the importance of developing multiliteracy-oriented assessments with STEAM approaches lies. Well-designed assessments can serve as teacher tools to facilitate interactive, integrative, and challenging learning. Such assessments must implement activities that not only emphasize cognitive aspects but also encourage students to explore ideas, solve problems, collaborate, and communicate their thoughts through various media (Trina et al., 2025; Utomo et al., 2018). Therefore, developing multiliteracy and STEAM assessments is an urgent need to realize transformative quality learning.

Although multiliteracy has shown promise in enhancing learning, studies examining its integration with STEAM in assessment contexts remain limited. Existing research rarely addresses how to evaluate critical thinking, creativity, collaboration, and communication within integrated, cross-disciplinary tasks (Normore et al., 2024; Wang, 2024). This gap highlights the need for empirical studies to develop coherent assessment frameworks that translate the theoretical connections between multiliteracy and STEAM into practical, skill-oriented evaluation. Most junior high school mathematics assessments still focus on cognitive abilities with single-answer options, such as multiple-choice tests or conventional essay questions (Henríquez-Rivas & Vergara-Gómez, 2025; Thornhill-Miller et al., 2023). Such instruments are less capable of measuring critical thinking and creativity skills because they primarily rely on closed-ended items that fail to capture students' complex reasoning, problem-solving strategies, and innovative thought processes. In other words, there is a gap between learning objectives that emphasize creativity and critical thinking and the assessment practices used in classrooms (El Bedewy et al., 2024).

Based on these conditions, this study aims to develop and test the effectiveness of multiliteracy-oriented assessments based on STEAM approaches designed to enhance the creativity, critical thinking, collaboration, and communication skills of secondary school students (Supianti et al., 2025; Thornhill-Miller et al., 2023). This assessment is compiled through project-based and contextual approaches, so students can learn through authentic activities that reflect real-life challenges while developing various types of literacy relevant to current conditions (Setiyani et al., 2025; Setiyani et al., 2024; Syukri et al., 2022). This multiliteracy assessment will also facilitate collaborative, reflective, and innovative learning processes with interdisciplinary approaches to strengthen multiliteracy concepts.

This research is expected to make theoretical contributions to strengthening the integration of multiliteracy and STEAM concepts in the development of learning materials. In practice, this multiliteracy assessment can be a concrete solution for teachers in implementing classroom instruction. Empirically, this study's findings will provide data to assess the effectiveness of this integrative approach in enhancing students' 4C skills. The novelty of this research lies in uniting multiliteracy and STEAM concepts in a systematically, measurably, and contextually designed multiliteracy learning assessment, which has been tested for effectiveness directly in the field. This multiliteracy assessment also emphasizes authentic, project-based learning relevant to students' daily lives while empowering students' various forms of literacy through project activities.

2. METHOD

2.1. Research Design

This study uses a Research and Development (R&D) approach adopting the ADDIE model, consisting of five main stages: analysis, design, development, implementation, and evaluation. The selection of this model is based on the clarity and systematicity of each stage, which align with research directions and objectives (Januarty et al., 2024). The ADDIE model development stages are shown in Figure 2.

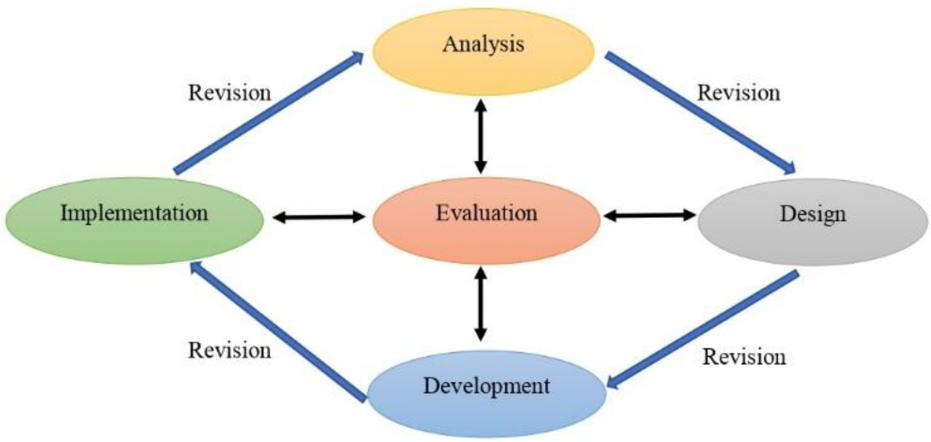


Figure 2. ADDIE model stage

2.1.1. Stage 1: (A) Analysis

The analysis stage was conducted to determine needs, identify problems, and analyze required development. At this stage, a needs analysis was performed to assess requirements and understand the difficulties students face in creativity, critical thinking, collaboration, and communication during learning. In this initial stage, researchers conducted literature reviews to identify theories and prior research. Furthermore, researchers also conducted learning observations and interviews with mathematics teachers. Observations focused on teacher strategies in learning processes, especially in implementing STEAM approaches. Interviews were conducted to determine the availability of assessments and teaching materials, their classroom implementation, and the challenges teachers face. Teacher and student needs regarding the availability of appropriate and effective multiliteracy assessments to develop creativity, critical thinking, collaboration, and communication skills were also considered in the development process.

Meanwhile, an analysis of multiliteracy assessments was conducted to ensure their readiness for use with STEAM approaches. Content analysis was performed to identify the methods used in teachers' multiliteracy assessments. Identified concepts served as the basis for developing multiliteracy assessments using STEAM approaches to enhance students' creativity, critical thinking, collaboration, and communication skills, named MASTER-4C. At the analysis stage, an evaluation was also conducted to determine the extent of teachers' needs and the alignment of existing assessments. This stage also evaluated the availability and implementation of multiliteracy assessments currently used in classroom practices to examine the extent to which they support the development of students' creativity, critical thinking, collaboration, and communication skills.

2.1.2. Stage 2: (D) Design

Activities at this stage involve developing the conceptual foundation of the multiliteracy assessment by defining and justifying the constructs to be measured. Drawing on multiliteracy theory and STEAM learning principles, five constructs: numeracy, scientific, digital, cultural, and financial literacy were identified as relevant domains and theoretically grounded. Each construct was then outlined and translated into preliminary indicators and task concepts to ensure alignment with established research and support a valid assessment design. The created MASTER-4C is adapted to geometry learning objectives through project activities. Additionally, the design includes scenarios or activities for students for each task and adapts to the applicable curriculum. The core of this activity is designing multiliteracy assessment product concepts as blueprints (initial designs). Furthermore, researchers designed assessment instruments to evaluate the quality of the developed multiliteracy assessments, focusing on validity, practicality, and effectiveness, as well as on 4C skills according to indicators.

A formative evaluation was conducted during the design stage to confirm the accuracy and feasibility of the initial multiliteracy assessment. Assessment experts reviewed the assessment concepts, task scenarios, and 4C-based indicators, and recommended refinements to improve alignment with geometry objectives and clarify the links between indicators and tasks. Their validation informed revisions to the blueprint, task flow, and scoring rubrics, ensuring alignment with STEAM principles before advancing to the development stage.

2.1.3. Stage 3: (D) Development

In the development stage, researchers conducted multiliteracy assessment development and activities, as well as projects that realized the multiliteracy assessment product design using previously designed STEAM approaches. MASTER-4C development was carried out in several steps: multiliteracy assessment, content construction, insertion of images relevant to the materials, and arrangement of activities that support creativity, critical thinking, collaboration, and communication skills. The development of MASTER-4C was validated by content experts, particularly in the field of assessment, and by media experts. Content validation was conducted by lecturers with more than 5 years of teaching experience in mathematics education, while media expert validators had at least 3 years of experience in their field. Validation of assessments provided in multiliteracy assessments, especially tasks directed toward improving creativity, critical thinking, collaboration, and communication skills through activities in geometry learning. Formative evaluation in the development stage used expert validation to ensure content accuracy, media quality, and alignment with multiliteracy and STEAM constructs. Expert feedback led to revisions in task clarity and 4C integration, after which the materials were finalized for implementation.

2.1.4. Stage 4: (I) Implementation

Implementation is the fourth stage of this process, in which the multiliteracy assessment is administered to eighth-grade students to gather reactions and feedback on the materials and assessments. This implementation aims to determine the practicality and effectiveness of MASTER-4C in enhancing students' creativity, critical thinking, collaboration, and communication skills. In this implementation stage, students were given several projects or activities based on the content of MASTER-4C, using STEAM approaches in geometry learning on plane figures. Additionally, researchers also conducted observations regarding students' creativity, critical thinking, collaboration, and communication skills while completing multiliteracy assessment activities. Evaluation during implementation assessed the practicality and instructional fit of the multiliteracy assessment in real classrooms. Student responses, task performance, and observations were used to identify issues in clarity, cognitive demand, and 4C skill enactment. These insights guided refinements to instructions and activity flow to better align with STEAM-integrated learning.

2.1.5. Stage 5: (E) Evaluation

The evaluation stage was conducted to determine the practicality and effectiveness of MASTER-4C in enhancing students' creativity, critical thinking, collaboration, and communication skills. This strategy began by analyzing assessment results from students, teachers, and validators for each instrument. These instruments were revised as deemed necessary and adjusted based on students' levels of creativity, critical thinking, collaboration, and communication.

2.2. Participants

This research was validated by six experts, comprising three content experts (Content Expert/CE) and three media experts (Media Expert/ME). The content experts consisted of three validators, all university lecturers with a minimum academic qualification of Associate Professor or a doctoral degree. CEs assessed relevance, accuracy, and integration aspects of STEAM-based content to ensure that learning materials support multiliteracy assessment development and 4C skills enhancement. MEs evaluated the design, interactivity, accessibility, and technological feasibility of learning media with emphasis on media capabilities in increasing student engagement and supporting 4C-oriented learning. Through this comprehensive validation process, the STEAM-based multiliteracy assessments developed were found to be pedagogically, technologically, and linguistically feasible for supporting 4C skills. During the implementation stage, two teachers participated in preliminary trials and provided suggestions through Forum Group Discussions on MASTER-4C instructional aspects.

Additionally, researchers also involved eighth-grade students who participated in field trials. This research was conducted at SMPN 3 Mojokerto in Mojokerto Regency, East Java, Indonesia. The selection of students used for field trials was conducted through random sampling, as all classes had received the same materials. The purpose of student involvement was to determine effectiveness, practicality, and responses, and to understand improvements in 4C skills after using MASTER-4C.

2.3. Research Procedures

This study employed a Level 4 development approach, which emphasizes the creation of innovative instructional products and their initial validation in authentic educational settings. The ADDIE model served as the primary development framework, guiding the systematic phases of Analysis, Design, Development, Implementation, and Evaluation. To examine the effectiveness of the developed product, the One-Shot Case Study design was applied during the Implementation and Evaluation stages, allowing preliminary effectiveness testing in real classroom conditions without the need for complex experimental controls.

The evaluation procedures involved implementing the MASTER-4C assessment within STEAM-integrated geometry learning, observing student performance, and collecting outcomes related to creativity, critical thinking, collaboration, and communication. These data informed judgments regarding the product’s feasibility and initial impact. Through this methodological integration, the study ensured that both development and evaluation were systematically conducted and pedagogically aligned with multiliteracy–STEAM learning principles.

2.4. Data Collection Techniques

This study used several data-collection techniques. First, observations using Likert scale questionnaires for validation by material experts, media experts, teachers, and students. Second, interviews aimed at exploring various aspects, such as opinions, aspirations, expectations, achievements, desires, and student beliefs regarding learning outcomes were conducted both as part of preliminary studies and continuously throughout the research to deepen understanding of learning dynamics. Third, documentation techniques aimed at recording all research activities, especially related to collaboration, creativity, critical thinking, and communication skills during MASTER-4C usage. In the data collection process, students were given individual and group tasks in the form of activities according to the MASTER-4C content.

2.5. Research Instruments

This study employed several data collection instruments, each constructed according to systematic procedures. First, interview guidelines for mathematics teachers and students were developed by identifying key indicators related to learning needs, student aspirations, motivation, engagement, and learning outcomes. Second, product validation questionnaires were constructed based on expert validation criteria, comprising separate rating sheets for media and material experts to evaluate the quality, accuracy, and relevance of the developed product. Practicality test questionnaires were then developed to measure the usability, clarity, and feasibility of the MASTER-4C product, involving both teachers and students as respondents. Finally, observation sheets were designed by operationalizing indicators of creativity, critical thinking, collaboration, and communication to monitor student activities and assess the preliminary effectiveness of MASTER-4C during implementation.

2.6. Data Analysis Techniques

Data analysis was conducted to evaluate the multiliteracy assessment with a STEAM approach across three dimensions: feasibility, practicality, and effectiveness, referring to criteria widely adopted in educational development research (Muhammad et al., 2025). easibility was examined using expert validation scores for material accuracy, media design quality, and linguistic clarity. Practicality was assessed through teacher and student responses regarding usability, clarity, and implementation feasibility in classroom settings. Effectiveness was analyzed through indicators of students' 4C skills. These dimensions were analyzed using descriptive statistics and expert judgment, enabling a concise yet rigorous assessment of MASTER-4C's feasibility, practicality, and preliminary effectiveness.

2.6.1. MASTER-4C Feasibility Validation Analysis

Analyzed data included suggestions and criticisms from experts and teachers, as well as student responses. Data analysis techniques were conducted as follows:

a. Data collection for the MASTER-4C indicator assessment was conducted systematically, including expert suggestions and criticisms, teacher feedback, and student responses. This data was collected comprehensively and analyzed to provide a complete picture regarding MASTER-4C quality and effectiveness, covering feasibility, practicality, and its impact on student skills. This process ensures a deep evaluation that supports improvement and further development of multiliteracy assessment.
b. Average value calculations for each assessment aspect indicator were performed using the following formula (Nurdalilah & Harahap, 2024):

$$\bar{x} = \frac{\sum x}{n}$$

Description:
$\bar{x}$ = average score
$\sum x$ = total assessor scores
n = number of validators

Results obtained from data analysis were subsequently converted into validity scores according to the established criteria (see Table 1). This process involves transforming raw data into scores that reflect validity levels against formulated standards or benchmarks. This way, validity data can be assessed objectively and adjusted against relevant criteria, enabling more accurate and measurable assessments of the instrument's quality and reliability (Nurdalilah & Harahap, 2024).

Table 1. Validation score conversion

Score Interval	Criteria
$3 \leq$ score < 4	Very high
$2 \leq$ score < 3	High
$1 \leq$ score < 2	Moderate
$0 \leq$ score < 1	Low

2.6.2. MASTER-4C Practicality Analysis

Data for the practicality analysis were collected by teachers and students. Questionnaire scores were calculated using equation (1), where "n" refers to the total number (Nurdalilah & Harahap, 2024).

$$\%\, p = \frac{score\ obtained}{\sum n} \text{ x } 100\% \qquad (1)$$

After obtaining an interpretation of the developed product, the next step is to convert it according to Table 2 (Nurdalilah & Harahap, 2024).

Table 2. Practicality test conversion

Percentage (%)	Criteria
0.00 – 20	Very low
20.1 – 40	Low
40.1 - 60	Moderate
60.1 – 80	High
80.1 – 100	Very high

2.6.3. MASTER-4C MASTER-4C Effectiveness Analysis

Data analysis of the effectiveness of MASTER-4C implementation during geometry learning in students was based on the activities. This research focused on 4C skills consisting of communication, collaboration, creativity, and critical thinking (Rudianto et al., 2022). To determine improvement in 4C skills, student activities using MASTER-4C were observed during three meetings.

Communication Skills Analysis

The percentage data on student communication skills were categorized into five criteria (Rudianto et al., 2022). The communication skills criteria are shown in Table 3.

Table 3. Communication skills criteria

Score	Criteria
80 ≤ NP ≤ 100	Very good
60 ≤ NP < 80	Good
40 ≤ NP < 60	Moderate
20 ≤ NP < 40	Low
0 ≤ NP < 20	Lowery Low

Collaboration Skills Analysis

The collaboration skills assessment data were analyzed across five categories to determine students' collaboration levels (Rudianto et al., 2022). Collaboration skills criteria are presented in Table 4.

Table 4. Collaboration skills criteria

Score	Criteria
81 – 100	Very good
61 – 80	Good
41 – 60	Moderate
21 – 40	Low
0 – 20	Lowery Low

Creativity Skills Analysis

Creativity skills test results were analyzed, and the extent of students' creativity skills was determined (Rudianto et al., 2022). The criteria for creativity skills are presented in Table 5.

Table 5. Creativity skills criteria

Score	Criteria
80 < NP ≤ 100	Very creative
60 < NP ≤ 80	Creative
40 < NP ≤ 60	Quite creative
20 < NP ≤ 40	Less creative
NP ≤ 20	Not creative

Critical thinking skills analysis

The critical thinking skills analysis results were then divided into four categories (Rudianto et al., 2022). Essential skills of thinking criteria are presented in Table 6.

Table 6. Critical thinking skills criteria

Score	Criteria
81.25 – 100	Very critical
62.50 – 81.24	Critical
43.75 – 62.49	Less critical
25.00 – 43.74	Not critical

Additionally, effectiveness was also viewed from 4C skills improvement at each meeting, shown in N-Gain calculations. This score is categorized as low when N-Gain score ≤ 0.30, moderate category when $0.30 <$ N-Gain Score ≤ 0.70, and high category when N-Gain score ≥ 0.70.

3. RESULTS AND DISCUSSION

Based on research results conducted by researchers referring to ADDIE stages, including analysis, design, development, implementation, and evaluation. Each stage provides a systematic framework for evaluating and compiling development research results from multiliteracy assessments. The following are detailed research results conducted in reference to the ADDIE stages.

3.1. Results

3.1.1. Analysis

This stage began by identifying the creativity, critical thinking, collaboration, and communication skills needed for each student. This stage was conducted using several methods: interviews, observations, and documentation. Interviews were conducted with teachers at SMPN 3 Mojokerto, especially teachers who taught mathematics. This was done to understand the approaches teachers used during learning and the implementation of the STEAM approach in schools. Interview results with teachers showed that creativity, critical thinking, collaboration, and communication skills were still low, especially in geometry subjects. Teachers only used books or multiliteracy assessments that tended more toward drill methods and memorization. Teachers did not yet have multiliteracy assessments that more closely aligned with developing students' skills through projects or activities. Teaching materials or multiliteracy assessments used by teachers had not yet integrated multiliteracy, especially with STEAM approaches. Teachers did not yet fully understand multiliteracy contexts or their implementation in classrooms. Teachers did not yet have teaching materials or multiliteracy assessments focused on developing creativity, critical thinking, collaboration, and communication skills.

Additionally, students were still not accustomed to projects or activities in both in- and out-of-class learning. Based on the analysis results and to better understand these needs, researchers proceeded to the design stage to develop learning materials in the form of MASTER-4C. Evaluation at this stage examined whether the interview, observation, and documentation data accurately captured gaps in teachers' practices and students' 4C skills. The findings were reviewed to confirm that issues such as limited multiliteracy integration, drill-based assessments, and low 4C performance in geometry were correctly identified as the basis for the design stage.

3.1.2. Design

Steps taken after needs analysis included: 1) creating flowcharts, 2) creating design sketches, 3) preparing and creating content materials, 4) combining obtained content into assessments, and 5) designing 4C skills instruments based on indicators. The design flowchart is shown in Figure 3.

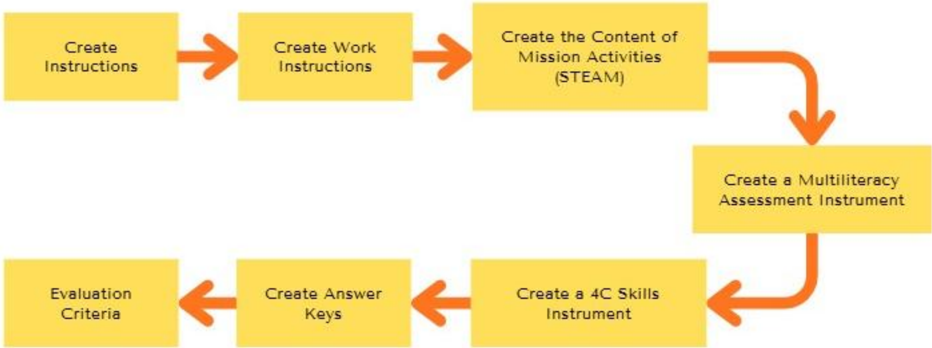


Figure 3. Flowchart of MASTER-4C

In the MASTER-4C design stage, the project began by designing attractive cover models for students. Multiliteracy assessment covers were created by adjusting contexts from each literacy and STEAM approaches. This aimed to make it easier for teachers and students to identify multiliteracy assessments to be used and learning objectives. Multiliteracy assessment covers were designed with consideration of layout, colors, materials, sub-materials, and applied approaches. To increase student interest in using multiliteracy assessments, colorful covers were used that linked to STEAM approaches.

Furthermore, the MASTER-4C content design was also conducted with skills to be enhanced in mind: collaboration, creativity, communication, and critical thinking. MASTER-4C was designed with a multiliteracy orientation, presented in five missions and four levels, with students progressing through them. There are five main missions that students must complete, each mission representing integration of multiliteracy aspects (language literacy, numeracy, science, digital, and cultural) with STEAM approaches. Each mission was arranged in the form of learning challenges that required students to think critically, collaborate, communicate effectively, and create innovatively. For example, the first mission focused on science literacy through simple experiments, the second mission on numeracy literacy with contextual mathematical problem-solving, the third mission on technology literacy through creating simple digital media, the fourth mission on cultural literacy through local wisdom exploration with arts approaches, and the fifth mission as a mini-project integration combining all STEAM elements.

To ensure gradual development, this multiliteracy assessment included four learning levels: Explorer, Challenger, Innovator, and Master. At the Explorer level, students were introduced to basic concepts through introduction and exploration activities. The Challenger level emphasized simple problem-solving practice and group work. The Innovator level encouraged students to design creative ideas or STEAM-based products. At the final level, Master's students were challenged to integrate all multiliteracy skills in the form of applicable final projects. With this mission and level structure, multiliteracy assessments were expected not only to improve material mastery but also to foster attitudes and skills relevant to junior high school students' needs. This evaluation examined whether the visual and structural design supported clarity, usability, and alignment with multiliteracy–STEAM goals, and whether each mission and level effectively targeted 4C skills through a coherent, progressively challenging pathway.

3.1.3. Development

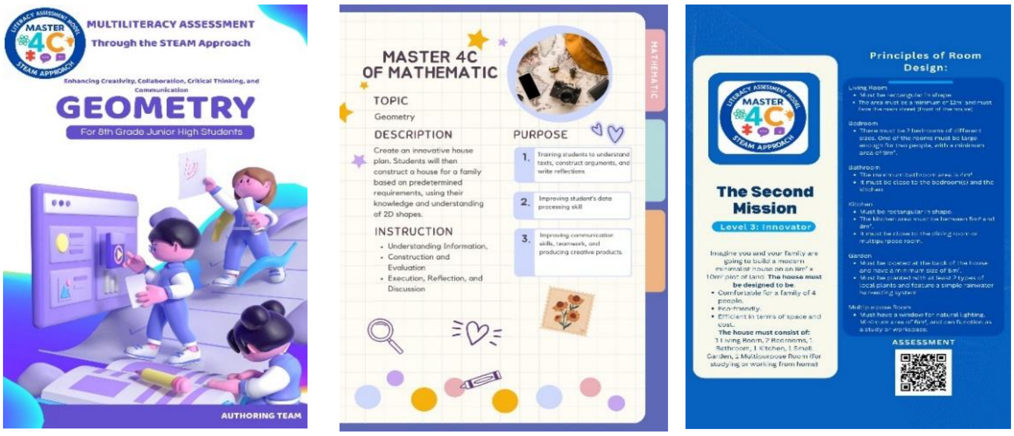
During the MASTER-4C development stage, several steps were taken to transform designed blueprints into final products. Development conducted included typing MASTER-4C material substance adapted to mission and level concepts. Additionally, image selection and context became essential considerations in the development of each page. Researchers utilized Microsoft Word and Canva applications to compile MASTER-4C. Researchers also gathered information from various sources to adjust materials to suit objectives. In this development stage, each multiliteracy assessment context was created differently for missions and levels within each project activity, using color variations and stories related to daily life to make it easier for students to understand multiliteracy assessments and to provide challenges in competing through assessment missions and levels. Researchers also paid attention to editing and layout arrangements to ensure proper and attractive element placement, so MASTER-4C could attract students to read and be easily understood. To strengthen this stage, the author should clarify how the design is theoretically grounded in multiliteracy and STEAM, and how selected images, contexts, missions, and levels align with the targeted constructs and indicators to validly measure 4C and multiliteracy skills.

Furthermore, the MASTER-4C development stage conducted an evaluation to ensure validity of use. Conducted validity referred to several aspects: media aspects, material substance aspects, and language aspects. In media aspects, there were three expert validators selected based on their competencies, while in material substance and language aspects, there were three expert validators selected based on their competency fields. Validation results for the media aspects, consisting of 7 statement items, are shown in Table 7.

Table 7. Recapitulation of media aspect validation results by ME validators

No	Criteria	Validator Scores		
		ME1	ME2	ME3
1	Cover suitability with discussion topics (mission, level)	4	3	4
2	Image size suitability displayed	4	3	4
3	Color usage displayed on MASTER-4C is attractive	3	4	4
4	Images displayed are suitable for missions and levels	4	3	4
5	The design displayed is attractive to students	3	3	3
6	Flow design in MASTER-4C can help students complete missions	3	3	4
7	Clear and easily understood instructions for each level	3	4	4
Total Score		**24**	**23**	**27**
Average per validator		**3.4**	**3.3**	**3.9**
Validator average			**3.53**	

Based on Table 7, the media validation assessment results from the three validators averaged 3.53, indicating that media aspects were in the very high category. Nevertheless, MASTER-4C for media aspects still had some elements that needed improvement, according to the validator's suggestions. MASTER-4C revision results, including the cover design and content display after revision per validator suggestions in the English version, are shown in Figure 4.



(a) (b) (c)

Figure 4. Display of MASTER-4C: (a) mathematics material cover; (b) introduction; (c) content display

Furthermore, researchers conducted validation using content experts (CE) as validators before MASTER-4C was used in STEAM-based learning activities. The following are validation results regarding material content, substance, and language in MASTER-4C (see Table 8).

Table 8. Content material validation data results from CE validators

No	Assessment Criteria	Validator Scores		
		CE1	CE2	CE3
1	Suitability of each creativity, critical thinking, collaboration, and communication skill indicator with competencies determined in MASTER-4C	3	4	4
2	The multiliteracy assessment given shows project activities leading to determined creativity, critical thinking, collaboration, and communication indicators	3	4	4
3	MASTER-4C has clear instructions and easily understood language for students	4	4	3
4	Story contexts presented in MASTER-4C show multiliteracy orientation through STEAM approaches	4	3	4
5	Created MASTER-4C can provide motivation to students to obtain information about daily life contexts based on STEAM	3	4	4
6	MASTER-4C content shows clear missions and levels	4	3	4
7	Missions and levels have suitability with creativity, critical thinking, collaboration, and communication skills	4	4	3
	Total CE validator scores	**25**	**26**	**26**
	Average per validator	**3.6**	**3.7**	**3.7**
	Average		**3.7**	

Based on expert (CE) validation results regarding MASTER-4C content, the average was 3.7. This indicates that content and language validation results were in the very high category for use. Thus, based on validation results across each aspect, MASTER-4C, through STEAM approaches, could be used at SMPN 3 Mojokerto to enhance collaboration, communication, creativity, and critical thinking skills.

3.1.4. Implementation

The MASTER-4C implementation was conducted in class 8G at SMP Negeri 3 Mojokerto for mathematics learning on plane figures. At the beginning of the lesson, students were engaged with trigger questions designed not only to activate prior knowledge of plane figures but also to scaffold critical thinking as an essential component of multiliteracy practices. Students were then encouraged to ask questions about unfamiliar concepts, which supported the development of communication skills through meaning negotiation. The formation of heterogeneous groups of 3–4 students was intentionally implemented to promote collaborative problem-solving, allowing learners with diverse abilities to complement one another in completing MASTER-4C tasks. The STEAM-oriented learning process further positioned students in contextual situations where they applied mathematical concepts through design-based projects accessed via QR codes. This approach integrates technological literacy and fosters creativity. Throughout these activities, teachers systematically observed student interactions to evaluate the development of collaboration, creativity, and communication as core 4C competencies within the multiliteracies and STEAM frameworks.

Students received geometry instruction on plane figures using MASTER-4C over three sessions, with each session featuring activities with various mission types and levels in progressive stages. This aimed to determine improvements in collaboration, creativity, communication, and critical thinking skills. One mission given to each group was to complete the second mission at level three (innovator) by creating a house floor plan design project with several requirements involving knowledge of the area and perimeter of plane figures. Each mission was multiliteracy-oriented, enabling students to understand all given statements and complete the mission accurately, using their creativity. Furthermore, each group was allowed to present their results to the class, while the other groups posed questions and provided responses. At the end of each session, teachers provided individual multiliteracy assessments to determine improvements in student critical thinking through MASTER-4C using STEAM approaches. Classroom implementation activities are shown in Figure 5.

Figure 5. Implementation of MASTER-4C in geometry learning

3.1.5. Evaluation

The evaluation stage encompasses the various phases completed in the development of the MASTER-4C product, including the analysis, design, development, and implementation stages. The MASTER-4C evaluation stage was conducted by two mathematics teachers and 32 students from class 8G. Instruments used were practicality and effectiveness assessment tools during MASTER-4C usage. The practicality score obtained from the average student responses was 91.50%, categorized as very high practicality (see Table 9).

Table 9. Student response recapitulation results for MASTER-4C

	Statement	Average Student Response Score
1	The MASTER-4C cover display makes me interested in reading	3.75
2	MASTER-4C color selection attracts my attention	3.63
3	The MASTER-4C presentation is not boring	3.81
4	MASTER-4C is equipped with several challenging missions and levels	3.56
5	Clear and simple language usage makes me easily understand the MASTER-4C material content	3.75
6	MASTER-4C concepts presented suit my understanding level	3.50
7	MASTER-4C enables me to complete tasks individually and in groups	3.63
	Average Score	**3.66**
	Practicality Conversion (%)	**91.50%**
	Criteria	**Very High**

In addition to student responses, the practicality score obtained from the average teacher responses was 87%, categorized as very high practicality (see Table 10).

Table 10. Teacher response recapitulation results for MASTER-4C

	Statement	Average Teacher Response Score
1	Learning materials or topics in MASTER-4C align with learning outcomes and objectives	3.6
2	Materials presented contextually based on multiliteracy with STEAM approaches	3.4
3	MASTER-4C contexts help students develop collaboration, creativity, communication, and critical thinking skills	3.2
4	Mission and level presentation suit student developmental stages	3.8
5	Systematic language usage helps students understand materials	3.4
	Average Score	**3.48**
	Practicality Conversion (%)	**87%**
	Criteria	**Very High**

Based on the Tables 9 and 10, the quality of the developed MASTER-4C met efficient criteria. Furthermore, the MASTER-4C effectiveness assessment was based on student activities during the mathematics learning process, focusing on improvements in collaboration, communication, and communication skills. Recapitulation: the percentage of results regarding learning implementation effectiveness was 87.5%. Learning conducted using MASTER-4C through STEAM approaches was very successful. Therefore, MASTER-4C could be implemented for several other learning contexts as appropriate. MASTER-4C received positive recognition and acceptance from teachers and students as support for material mastery in various subjects, such as mathematics for plane and solid figures. These results ensure that developed multiliteracy assessments are aligned with target user needs and could serve as alternative solutions for innovative assessments.

3.1.6. Impact of MASTER-4C on Students' 4C Skills

The focus on using multiliteracy assessments within STEAM approaches to enhance students' skills included communication, collaboration, creativity, and critical thinking. After using MASTER-4C across three sessions with various materials, researchers conducted observations to assess students' skills. Each skill had indicators used to evaluate students during group and individual tasks. Students were assigned group tasks of 4 people to complete missions according to their roles, along with multiliteracy assessments to determine individual evaluations. Communication skill results for each session were compared to understand the impacts of MASTER-4C usage. Student communication skills over three sessions are shown in Figure 6.

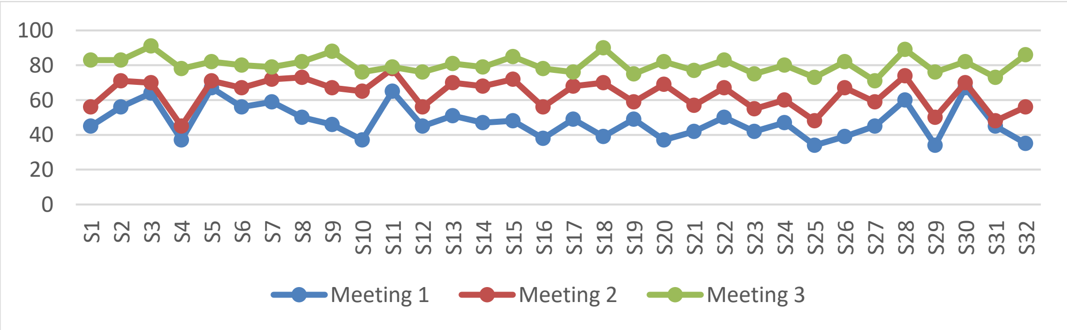


Figure 6. Student communication skills profile

Based on Figure 6, in the first session, most students were in the moderate category (36.7%), followed by the low (23.3%), good (20%), and very low (13.3%) categories, with only a small portion reaching the outstanding category (6.7%). In the second session, significant improvement occurred in the perfect (20%) and good (30%) categories, while the moderate category (33.3%) still dominated; the low category decreased to 16.7%, and the very low category no longer existed. In the third session, results showed greater improvement, with the majority of students in the good (43.3%) and excellent (36.7%) categories. In comparison, the moderate category decreased to 20%, and no students remained in the low or very low categories. These findings indicate an upward trend in student communication abilities, with apparent shifts toward higher categories after using MASTER-4C. Next, MASTER-4C usage results for collaboration skills are shown in Figure 7.

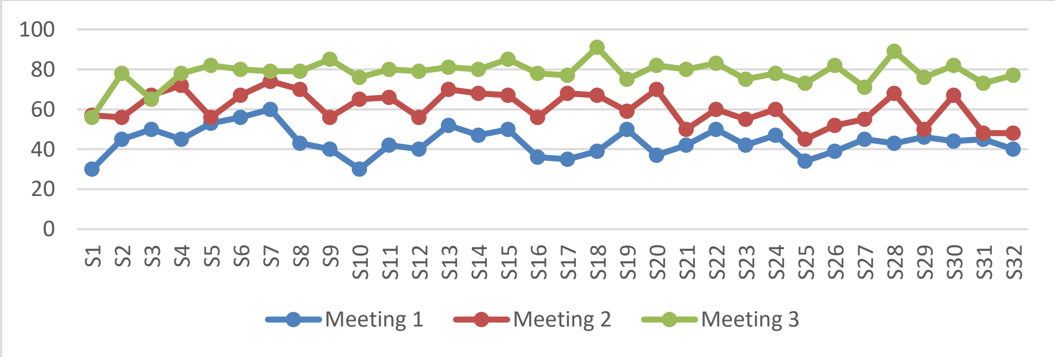


Figure 7. Student collaboration skills profile

Based on Figure 7, in the first session, most students were in the moderate category (59.4%), followed by the low category (37.5%), while only 3.1% were in the high category. In this first session, no students were in very high or very low categories. In the second session, the majority of students remained in the moderate category (53.1%), while the number in the high category increased significantly to 43.8%, with only 3.1% remaining in the low category. Subsequently, in the third session, a very significant improvement occurred, with the majority of students in the high category (62.5%) and the remainder reaching the very high category (37.5%). No students remained in moderate, low, or very low categories. These findings indicate progressive development of student collaboration skills across sessions, with clear trends from low and moderate categories toward high and very high categories. Next, MASTER-4C usage results for creativity skills are shown in Figure 8.

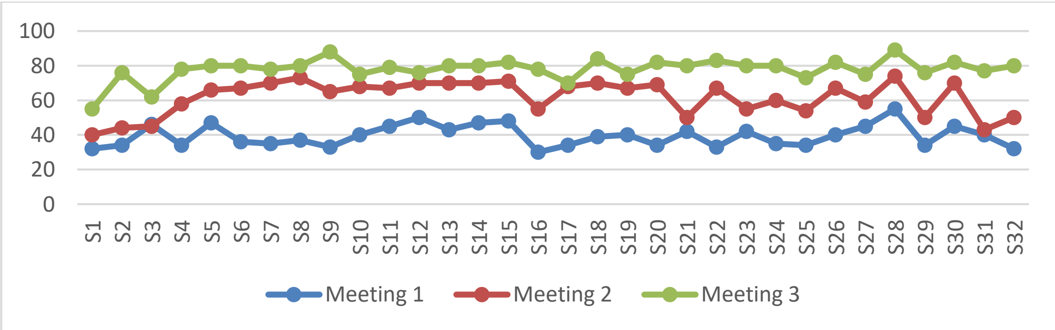


Figure 8. Student creativity skills profile

Based on Figure 8, in the first session, most students were in the less creative category (57.58%), followed by the quite creative category (42.42%). In contrast, no students reached the creative or very creative categories. In the second session, improvement occurred, with the majority of students entering the creative category (57.58%), followed by the quite creative category (39.39%); only a few students remained in the less creative category (3.03%), and no students reached the very creative category. Subsequently, in the third session, more significant increases occurred, with most students in the creative category (72.73%), followed by the very creative category (24.24%). In comparison, only 3.03% of students remained in the quite creative category, and no students remained in the less creative or not creative categories. Next, MASTER-4C usage results for critical thinking skills are shown in Figure 9.

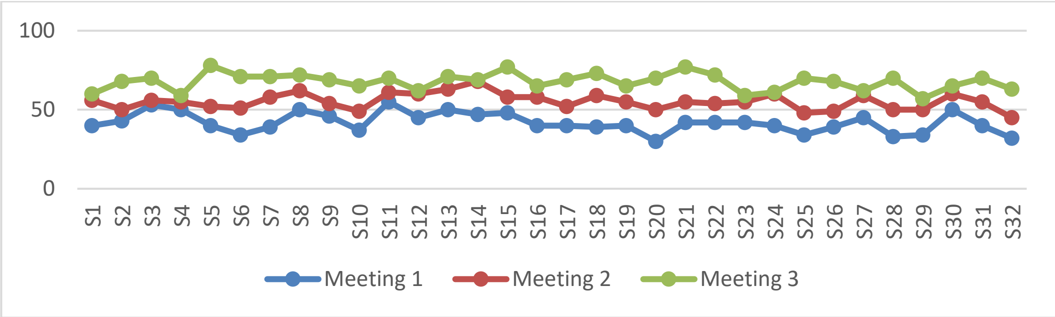


Figure 9. Student critical thinking skills profile

Based on Figure 9, in the first session, most students were in the not critical category (66.67%), while the remainder were in the less critical category (33.33%), and no students reached the critical or very critical categories. In the second session, improvement occurred, with the majority of students entering the less critical category (93.94%) and only 6.06% entering the critical category. Subsequently, in the third session, significant improvement was evident, with most students in the critical category (78.79%), followed by less critical (21.21%), and no students remained in the not critical or very critical categories. Furthermore, MASTER-4C's impact on each skill improvement is shown in Table 11.

Table 11. 4C skills improvement profile recapitulation

Skills	**Average Scores**			**N-Gain**	**Category**
	Session 1	**Session 2**	**Session 3**		
Communication	47.66	63.56	80.31	0.62	Moderate
Collaboration	43.66	60.78	78.28	0.62	Moderate
Creativity	39.41	61.63	77.79	0.63	Moderate
Critical Thinking	41.84	55.22	67.75	0.45	Moderate

Comparisons of communication, collaboration, creativity, and critical thinking skills show increasing trends across sessions. For communication skills, the initial average was 47.66 and the final average was 80.31, with an N-Gain of 0.62 (moderate). For collaboration skills, the initial average was 43.66 and the final average was 76.28, with an N-Gain of 0.62 (mild). For creativity skills, the initial average was 39.41 and the final average was 77.79, with an N-Gain of 0.63 (moderate). Finally, critical thinking skills had an initial average of 41.84 and a final average of 67.75, with an N-Gain of 0.45 (mild). This indicates that all skills experienced improvement, with creativity skills showing the highest improvement and critical thinking skills the lowest (see Figure 10). Thus, MASTER-4C use with STEAM approaches can support improvements in communication, collaboration, creativity, and critical thinking skills among secondary school students across various multiliteracy subjects. Therefore, the developed MASTER-4C is capable of enhancing 4C skills in accordance with its development objectives.

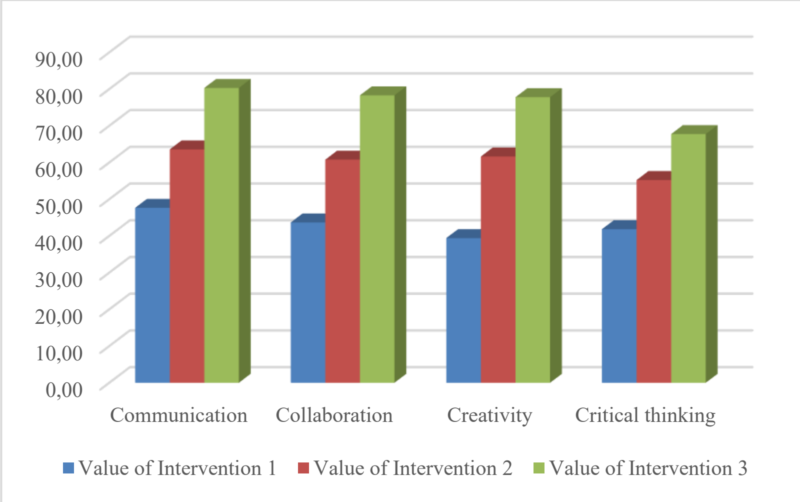


Figure 10. 4C skills comparison profile for each session

3.2. Discussion

The multiliteracy-based assessment model integrated with STEAM, referred to as MASTER-4C, was developed to support geometry learning on plane figures and to foster students' communication, collaboration, critical thinking, and creativity. Rather than emphasizing its structural features, the present discussion focuses on how the model's implementation informs the development of these competencies and elucidates its theoretical and instructional significance. The development process in this research began with literature reviews, field observations, and interviews with teachers and students to ensure user needs served as the basis for the initial analysis. MASTER-4C emphasizes the main concepts of plane figures, including definitions, characteristics, surface area, and perimeter. To support use, this assessment includes guidelines and assessment criteria (rubrics) for teachers as references during evaluation.

Meanwhile, student assessments are fitted with printed books containing worksheets integrated with technology. Additionally, this assessment features several levels and missions to provide challenges and motivation for students while serving as a reference for teachers to categorize students by ability. Experts have validated MASTER-4C development to ensure product consistency with objectives. The average validation results for ME and CE were 3.53 and 3.7, respectively, both categorized as very valid. These results indicate that the developed MASTER-4C, with its content and media, suits student needs. This high validity also confirms that constructed assessments meet reasonable quality standards regarding content relevance and media feasibility for enhancing communication, collaboration, critical thinking, and creativity skills (Asman et al., 2022; Castellano-Sanz & Reyes-Torres, 2024).

The implementation of MASTER-4C in geometry learning creates structured opportunities for students to engage in inquiry, problem-solving, and collaborative meaning-making through progressively challenging project tasks. Although the model incorporates four performance levels (Explorer, Challenger, Innovator, and Master) and STEAM-aligned missions, the primary significance lies in how these staged tasks activate multiliteracy practices and interdisciplinary reasoning, thereby supporting the development of communication, collaboration, critical thinking, and creativity. Each mission is designed as activities that can be completed individually or in groups, with the mission objectives in geometry learning in mind. Additionally, activities constructed in each mission and level require creativity skills in creating products, communication in asking questions and presenting work results, collaboration in teamwork, and critical thinking for problem-solving. Content presentation includes contextual stories based on multiliteracy and connected to plane figure concepts in geometry learning. Using the MASTER-4C model in geometry learning provides unique opportunities by integrating learning levels and project-based missions aligned with STEAM approaches. Research by Beltrán-Palanques (2024), Castellano-Sanz and Reyes-Torres (2024), and Yim et al. (2024) shows that project-based learning in STEAM contexts can enhance students' cognitive engagement and foster formative environments that support mathematical exploration. This aligns with the Explorer, Challenger, Innovator, and Master-level designs in MASTER-4C, which gradually adapt to students' abilities.

Furthermore, research by Chappell et al. (2025) and Rudianto et al. (2022) confirms that STEAM is effective in developing 21st-century skills, particularly 4C skills that form the core of each mission in MASTER-4C. Additionally, Trina et al. (2025) found that STEAM implementation through cultural contexts and architectural modeling practices can strengthen creativity and collaboration, supporting the use of multiliteracy-based contextual stories in geometry learning. This support is reinforced by research from Asman et al. (2022) emphasizing the importance of project narratives for enhancing communication and presentation skills. Thus, MASTER-4C is not only theoretically relevant but also has strong empirical foundations for improving mastery of the geometry concept while fostering STEAM-based multiliteracy skills.

Research results on MASTER-4C implementation satisfaction in geometry learning indicate high levels of satisfaction. Teachers and students responded positively and showed interest in the given assessment model. Used assessments could motivate creativity through challenging activities on plane figure materials. Easy-to-understand language usage in each context and attractive design. Average student and teacher response results were 3.66 and 3.48, with practicality conversions of 91.50% and 87% respectively, categorized as very high practicality.

Additionally, learning implementation effectiveness was 87.5%. Learning conducted using MASTER-4C through STEAM approaches could be considered highly successful. Using project- and activity-based media could provide students with motivation and challenges. This increased student interest and enabled students to explore creativity, critical thinking, communication, and collaboration skills during the learning process (Barta et al., 2022; Zhao et al., 2024). Furthermore, learning supported by multiliteracy assessments grounded in STEAM approaches yielded exemplary outcomes in developing students' 4C skills. Using uniquely designed multiliteracy assessments with levels and missions, and integrating technology through QR codes, provided optimal value.

The improvements in students' 4C skills can be attributed to MASTER-4C's operationalization of the STEAM framework in its task design. The Science component is embedded through observation and evidence-based reasoning when analyzing geometric phenomena; Technology supports diverse forms of exploration using digital tools; Engineering is represented through iterative design, testing, and refinement processes integrated into project missions; the Arts component facilitates visual representation and narrative composition, strengthening multiliteracy practices; and Mathematical reasoning underpins abstraction and problem structuring. These integrated mechanisms collectively create interdisciplinary learning conditions that theoretically support and empirically enhance communication, collaboration, critical thinking, and creativity. Data analysis shows communication skill average score improvements with N-Gain scores of 0.62 in the moderate category. For collaboration skills, with N-Gain scores of 0.62 in the mild category. N-Gain scores for creativity skills were 0.63 in the mild category. For critical thinking skills with N-Gain scores of 0.45 in the moderate category. Thus, average skill calculations across sessions show improvements in MASTER-4C usage. This indicates MASTER-4C potential in supporting communication, collaboration, creativity, and critical thinking skills. However, it is essential to note that improvements in crucial aspects of thinking have not yet reached advanced levels, because students are not yet accustomed to solving complex, open-ended problems. Therefore, learning strategies that emphasize the development of deep analytical, evaluative, and reflective skills are needed so that students can not only be critical but also achieve very high levels of critical thinking. Overall, MASTER-4C can comprehensively facilitate each 4C skill indicator, contributing positively to enhancing communication, collaboration, creativity, and critical thinking during geometry learning.

4. CONCLUSION

Multiliteracy assessment models with STEAM approaches in geometry learning, oriented toward enhancing 4C skills (communication, collaboration, creativity, and critical thinking), were successfully developed using ADDIE model procedures. The resulting assessment model was named "MASTER-4C," equipped with several missions and levels. Based on the data analysis, the MASTER-4C validation aspects were categorized as having very high validity. From a practical perspective, the average scores from mathematics teachers and students were 91.50% and 87%, respectively. In the effectiveness analysis, significant improvements in 4C skills were observed with MASTER-4C across three sessions. N-Gain scores for communication skills were 0.62 (moderate), collaboration skills were 0.62 (mild), creativity skills were 0.63 (moderate), critical thinking skills were 0.45 (moderate), and geometry learning implementation results were 87.5%. Therefore, MASTER-4C meets development quality standards for validity, practicality, and effectiveness in enhancing 4C skills.

This research successfully developed products to facilitate the development of 4C skills. However, limitations need attention, including optimizing mission contexts to foster a culture that supports cultural literacy and student critical thinking, and ensuring control group involvement in research designs, particularly across other subjects and materials. Additionally, this research remains limited to a small sample size. Future studies should investigate how multiliteracy-based and STEAM-integrated tasks specifically drive the development of 4C skills using a controlled comparative design. Building on the notable improvements identified in this study, researchers can further examine whether these gains stem from STEAM components, multiliteracy processes, or their interaction, and test these effects across diverse learners and contexts to strengthen the empirical basis for refining and expanding MASTER-4C.

Furthermore, broader research samples involving students from various schools as participants are needed. Adding context focused more on each skill indicator to better represent students' 4C skills. Although the study shows that a multiliteracy-STEAM assessment can improve 4C skills to a limited extent, it also highlights MASTER-4C's contribution to multiliteracies research and mathematics assessment. It's clear that STEAM integration also provides a basic framework for developing more coherent STEAM-based interdisciplinary evaluations.

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Declarations

Author Contribution	: ESU: Conceptualization, Data collection, Funding acquisition, Investigation, Methodology, Resources, and Writing - original draft; C: Formal analysis, Methodology, Writing - original draft, and Writing - review & editing; AF: Supervision, Validation, Visualization, and Writing - review & editing.
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Conflict of Interest	: The authors declare no conflict of interest.
Additional Information	: Additional information is available for this paper.

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