



STEM-IOT INTEGRATION IN PAPER BRIDGE PROJECTS: DEVELOPMENT OF A LEARNING TOOL FOR TEACHING RATIO AND PROPORTION

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ABSTRACT

Mathematics remains underrepresented in integrated STEM practice, and ratio and proportion, despite lending itself to authentic design tasks, is a topic students persistently struggle to master, with no prior development research combining a paper bridge project and a student-built IoT weight scale to teach it. This study developed and examined the content validity of a STEM-PjBL learning tool, comprising a teaching module, student worksheet, and assessment instrument, that integrates a paper bridge project with a student-built IoT weight scale to teach ratio and proportion to seventh-grade students through a six-phase Engineering Design Process (Ask, Research, Imagine, Plan, Create, Improve). Using a Research and Development approach limited to the Analysis, Design, and Development stages of the ADDIE model, the initial draft was validated by two mathematics education lecturers and analyzed using Gregory's content-validity formula. All three components, teaching module, student worksheet, and assessment instrument, achieved a validity index of 1.00 across all rated aspects, placing them in the high-validity category, and were subsequently revised based on the validators' qualitative feedback. These findings indicate that the developed STEM-PjBL tool is content-valid and ready for classroom trial, offering a concrete model for embedding authentic, student-generated data into mathematics instruction and narrowing the disciplinary gap between IoT-based STEM tools and mathematics learning.

Keywords: STEM-PjBL; Ratio and Proportion; IoT; Validity; Paper Bridge

1. INTRODUCTION

Quality and equitable education for all remains a central priority in global development, as reflected in Sustainable Development Goal 4 (SDG 4), which emphasizes inclusive access to relevant and effective learning outcomes for every learner [26]; [30]. Within this agenda, Science, Technology, Engineering, and Mathematics (STEM) education has been widely promoted as an interdisciplinary approach connecting scientific inquiry, engineering design, technology, and mathematical reasoning within authentic real-world contexts [5]; [12]. Scholarly interest in mathematics within STEM has grown steadily, with publication counts nearly doubling between 2015 and 2024 [17], and meta-analytic evidence confirms that STEM-based instruction produces significantly better learning outcomes than conventional approaches [6].

Despite this attention, mathematics remains underrepresented within integrated STEM practice, as design activities are more often built around physical phenomena than explicit mathematical objectives, and technology and mathematics typically receive less emphasis than science and engineering [29]. This imbalance is concerning because ratio and proportion, including scale, direct and inverse proportion, and rate of change, is content that naturally lends itself to authentic, design-based tasks, yet a systematic review has shown that students persistently struggle to grasp it even after decades of curricular focus [28]. The problem is acute in Indonesia: national mathematics literacy fell from a PISA score of 379 (2018) to 366 (2022), ranking around 70th of 81 countries and roughly 100 points below the OECD average [19]. Classroom-based studies confirm specific difficulties: error analyses using the Kastolan framework found students commit conceptual, procedural, and technical errors on ratio word problems, most often failing to grasp ratio as a comparison between two quantities [24]; and four-tier diagnostic studies report frequent confusion between direct and inverse proportion, alongside errors in defining key terms and formulating problems mathematically [2]. Together, this evidence suggests conventional, procedure-driven instruction is insufficient, and that authentic, hands-on learning experiences are needed.

Project-Based Learning integrated with STEM (STEM-PjBL) is a promising response, theoretically grounded in Kolb's [14] experiential learning cycle, which holds that meaningful learning occurs as learners move through concrete experience, reflective observation, abstract conceptualization, and active experimentation. Empirical studies support this in mathematics classrooms: STEM-PjBL-based learning tools have been developed and rated valid, practical, and effective at strengthening students' critical thinking [11] and collaboration skills [32]. However, most of these studies still reduce the "technology" and "engineering" components to simple manual artifacts, such as posters, physical models, paper constructions, or digital comics, without an authentic cycle where students build and use a real instrument to collect data that feeds back into the mathematical analysis.

A related area of research has examined the use of Internet of Things (IoT) devices, typically Arduino or ESP32 microcontrollers paired with low-cost sensors, in STEM instruction. Arduino-based instruments have been designed and validated as teaching materials for physics concepts such as the work-energy theorem, allowing students to generate and analyze real experimental data rather than relying on textbook values [7]. Beyond content delivery, an Arduino-based air-quality-sensor program for high school students produced significant gains in math/science self-efficacy and collaborative behavior, with students reporting increased confidence after building and debugging their own devices [20]. Yet in both of these studies, and across the broader literature on Arduino and IoT-based STEM instruction, the target domain remains physics or environmental science. In contrast, mathematics classrooms, and ratio and proportion instruction in particular, have rarely served as a site for this kind of student-built measurement instrument, leaving a clear disciplinary gap.

The paper bridge activity is a recognized authentic STEM context: sixth-graders using it to design, test, and redesign a load-bearing bridge demonstrated genuine integrated STEM reasoning [9]. Still, the mathematical focus there was justification and interpretation, not ratio and proportion as an explicit objective, and load was measured manually, as in informal lesson plans from STEM centers such as WPI and Science Buddies, rather than with a purpose-built instrument. Two systematic reviews of technology in ratio and proportion learning confirm the field is dominated by games, web platforms, and AR/VR, with no evidence of physical, student-built measurement tools [22]; [16]. No development research has combined a paper bridge project, in which ratio is taught through the scale relationship between a full-size bridge and its miniature version, with a student-built IoT weight scale that generates the load data used to test that design. The two have not been validated together as a single, classroom-ready tool.

This study develops and validates a STEM-PjBL mathematics learning tool that combines a paper bridge project with a student-built IoT weight scale to teach ratio and proportion to seventh-grade students. The tool, consisting of a teaching module, student worksheet, and assessment, follows a six-phase engineering design process, namely Ask, Research, Imagine, Plan, Create, and Improve, adapted from the STEM-based EDP framework [1], during which students determine the bridge-to-miniature ratio, construct the miniature, assemble an IoT weight scale, and evaluate its load capacity. Evaluating that capacity depends on ratio as well. The load cell outputs a raw signal proportional to the applied force, and calibrating the sensor means comparing that signal to a known reference weight to obtain a single conversion factor. Every subsequent raw reading is then converted to an actual weight value using that same factor. Once calibrated, the real-

time weight readings give students numeric evidence to check whether a design's actual load-bearing capacity stays proportional to the ratio used to scale it down.

2. RESEARCH METHODOLOGY

This study used a Research and Development (R&D) approach with the ADDIE model [3], limited to the Analysis, Design, and Development stages. The Analyze phase identified students' difficulties and learning needs on ratio and proportion material. The Design phase produced the initial draft of the STEM-PjBL learning tool, which consists of a teaching module, student worksheet, and assessment instrument, follows the Ask, Research, Imagine, Plan, Create, Improve phases [1]. In the Develop phase, the first draft was validated by 2 validators, both mathematics education lecturers, before being revised into the final development stage product.

2.1. Research Instrument

The validation sheets used a 4-point Likert scale (Table 1) with an open-comment column.

Table 1. Validation Rating Scale

Score	Category
4	Strongly Agree
3	Agree
2	Disagree
1	Strongly Disagree

[31]

The teaching module was validated on six aspects: content, presentation, language, learning activities, STEM, and Engineering Design Process characteristics, adapted from the BSNP teaching-material feasibility criteria [4] and the STEM-EDP indicators used by [23]. The student worksheet was validated on content eligibility, language, presentation, and graphical aspects, adapted from the BSNP feasibility instrument for teaching materials [4]. The assessment instrument was validated on content suitability, construction, and readability, adapted from the national assessment standard [8].

2.2. Data Analysis Technique

Scores obtained from the validation sheets were converted into a dichotomous category to determine the validity of the teaching module, student worksheet, and assessment instrument. Scores of 1–2 (Strongly Disagree/Disagree) were categorized as Weak, while scores of 3–4 (Agree/Strongly Agree) were categorized as Strong [10]. The categorized results from the two validators were then arranged into a contingency table, as presented in Table 2. Contingency Table

Table 2. Contingency Table

Validator	Combination 1	Combination 2	Combination 3	Combination
Validator 1	Weak	Weak	Strong	Strong
Validator 2	Weak	Strong	Weak	Strong
Total	A	B	C	D

Where A is the number of items rated Weak by both validators, B and C are the number of items on which the two validators disagreed, and D is the number of items rated Strong by both validators. The validity index was then calculated using Gregory's formula [10]:

$$\text{Validity Index} = \frac{D}{A+B+C+D}$$

The resulting index was interpreted using the criteria presented in Table 3.

Table 3. Interpretation of Validity Index

Score	Category
0.71-1	High validity
0.41-0.70	Moderate validity
0-0.40	Low validity

[10]

The teaching module, student worksheet, and assessment instrument were declared valid if the validity index reached at least the high category.

3. RESULTS AND DISCUSSION

This study followed three stages of the ADDIE model, namely Analysis, Design, and Development stages, to produce a STEM-PjBL learning tool that teaches ratio and proportion through a paper bridge project supported by a student-built IoT weight scale. The results of each stage are presented below.

3.1. Analysis

The Analysis phase comprised curriculum, student needs, and material–technology analysis. The curriculum review identified ratio and proportion as a key competency for Phase D (Grade VII) mathematics, requiring students to apply concepts of scale, proportion, and rate of change in problem solving. Although mathematics plays a central role in STEM education, it is often underrepresented in integrated STEM activities, which tend to emphasize science and engineering over mathematical reasoning [29], despite growing attention to mathematics integration and evidence that STEM-based instruction is more effective than conventional approaches [17]; [6]. Student needs analysis further highlighted the urgency of this issue, as previous studies reported that students frequently struggle to understand ratio as a comparison between quantities and to distinguish between direct and inverse proportion [24]; [2]. Finally, the material and technology analysis revealed that existing STEM-PjBL learning tools commonly rely on manual artifacts without authentic data collection, while student-built Arduino- and IoT-based technologies have rarely been applied to ratio and proportion learning [7]; [20]. Although the paper bridge project has been recognized as an authentic STEM context [9], reviews of technology integration found no studies employing a student-assembled IoT measurement device for this topic [22]; [16]. IoT weight scale's role in this design is to measure, in real time, the load the paper bridge can bear. Its calibration procedure is also a direct application of proportion, so the ratio and proportion objective applies to the IoT component as well as to the bridge design. Therefore, the learning tool was designed to integrate a paper bridge project with a student-built IoT weight scale using the six-phase Engineering Design Process [1].

3.2. Design

Based on the analysis findings, an initial draft of the STEM-PjBL learning tool was produced, consisting of a teaching module, a student worksheet, and an assessment instrument. This draft became the object of expert validation in the Develop phase.

3.2.1. Teaching Module Draft

The initial design of the teaching module was developed based on the learning objectives and learning outcomes that had been formulated in the Analysis phase, adjusted to the STEM-PjBL syntax and the six-phase engineering design process (Ask, Research, Imagine, Plan, Create, Improve). The module was designed using Canva, covering general information (topic, phase/grade, time allocation, learning approach), core components (learning objectives, meaningful understanding, guiding questions, and Pancasila Student Profile), the STEM component map linking mathematics, engineering, science, and technology to the paper bridge problem, the two-meeting lesson activities, and a reflection section for both teachers and students. Within the STEM component map, the IoT weight calibration step shows students how a sensor's raw output can be turned into a meaningful weight using ratio. The raw reading has no unit, so it must be compared with a known mass. Students place a reference weight on the sensor, record the reading, and divide the known mass by that value to get a conversion factor. This factor is then multiplied by future readings to obtain weight in grams. The activity is done in the first lesson before building the paper bridge, so students can apply the same ratio concept later when testing the bridge. An example of the teaching module draft is presented in Figure 1.



Figure 1. Teaching Module Draft

3.2.2. Student Worksheet Draft

The initial design of the student worksheet (LKPD) was developed to guide students through the six-phase engineering design process in constructing the paper bridge and IoT weight scale. The worksheet was designed using Canva, consisting of a cover page for group identity, task instructions (materials, time limit, and bridge specifications), and structured activity sheets corresponding to each EDP phase, namely Ask (the triggering problem and design question), Research (project instructions), Imagine (sketch design), Plan (activity schedule), Create (construction process and load-testing results), Improve (evaluation and redesign), and a final reflection sheet. An example of the student worksheet draft is presented in Figure 2.

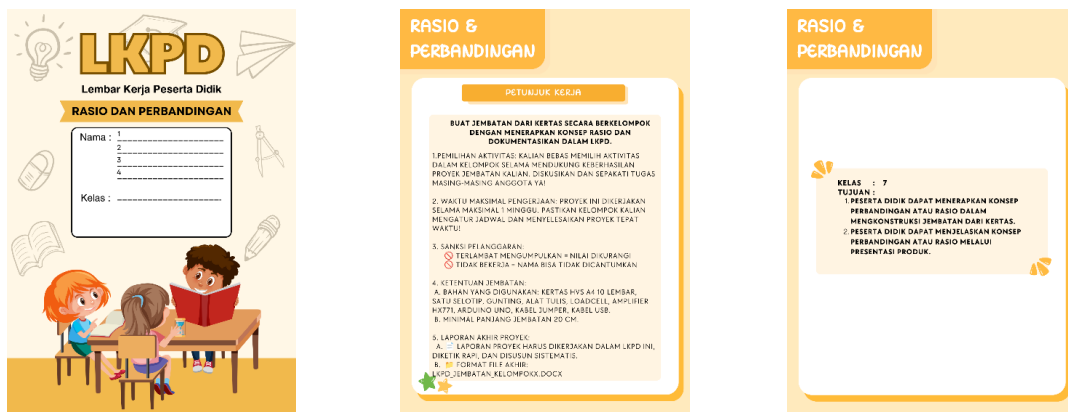


Figure 2. Student Worksheet Draft

3.2.3. Assessment Instrument Draft

The initial design of the assessment instrument was developed to measure students' understanding of ratio and proportion as well as their performance during the project. The instrument consists of a teacher observation questionnaire and a peer/student self-assessment questionnaire, each rated on a five-point scale covering design accuracy, creativity, collaboration, time management, structural strength, and presentation quality, and a multiple-choice summative test of five items on ratio and proportion accessed through an online form. The structural strength criterion is scored directly from the IoT weight scale, which measures

the load on the paper bridge in real time and records the maximum load the design can bear before it fails. An example of the assessment instrument draft is presented in Figure 3.

ANGKET PENILAIAN GURU

Nama Kelompok :
 Anggota Kelompok :
 1.
 2.
 3.
 4.

Petunjuk : Beri centang (✓) pada setiap nomor sesuai dengan kriteria yang dinilai berdasarkan kinerja kelompok (1=sangat kurang, 2=kurang, 3=cukup, 4=baik, 5=sangat baik).

No	KRITERIA PENILAIAN	SKOR				
		1	2	3	4	5
1.	Keseriusan Desain Jembatan dengan prinsip Matematika dan Teknik					
2.	Kreativitas dalam pemilihan dan pengolahan bahan kerja					
3.	Kerja sama dan Komunikasi antar anggota kelompok					
4.	Efektifitas waktu dan manajemen proyek					
5.	Kekuatan struktur jembatan saat uji beban minimal 2 kg					
6.	Kualitas presentasi hasil dan penjelasan konsep					

Bobot nilai:
 1. Keseriusan Desain Jembatan dengan prinsip Matematika dan Teknik 20%
 2. Kreativitas dalam pemilihan dan pengolahan bahan kerja 10%
 3. Kerja sama dan Komunikasi antar anggota kelompok 10%
 4. Efektifitas waktu dan manajemen proyek 10%
 5. Kekuatan struktur jembatan saat uji beban 30%
 6. Kualitas presentasi hasil dan penjelasan konsep 10%

ANGKET PENILAIAN SISWA

Nama Penilai :
 Nomor Presensi :
 Kelas :
 Nama anggota kelompok :
 1.
 2.
 3.
 4.

Petunjuk : Beri centang (✓) pada setiap nomor sesuai dengan kriteria yang dinilai berdasarkan kinerja peserta didik yang dinilai (1=sangat kurang, 2=kurang, 3=cukup, 4=baik, 5=sangat baik).

Nama yang dinilai :
 Nomor presensi :
 No.

No.	Kriteria	Skor				
		1	2	3	4	5
1.	Ikut serta dalam diskusi perancangan jembatan.					
2.	Berkontribusi aktif saat proses pembuatan jembatan.					
3.	Memahami dan menjelaskan konsep perbandingan dan rasio yang digunakan.					
4.	Menjalin kerja sama yang baik dan saling membantu dalam tim.					
5.	Terlibat dalam menyiapkan dan menyampaikan presentasi hasil proyek kelompok.					

Total nilai : x 4

Penilaian Sumatif Rasio dan Perbandingan

Kerjakan penilaian sumatif berikut secara mandiri untuk mengukur pemahaman tentang materi rasio dan perbandingan.

Latihan 2224Apakah sama di 4? [Bantu di sini](#)

Totol atikikan

* Menunjukkan pertanyaan yang lebih di atas

Nama *

Jawaban Anda

Nomor Presensi *

Jawaban Anda

Kelas *

Jawaban Anda

Belilah jembatan dibagi menjadi tiga bagian dengan rasio panjang A : B : C = 1 : 2 : 3. Jika panjang total jembatan adalah 100 cm, berapa panjang masing-masing bagian?

☐ A = 25 cm, B = 30 cm, C = 45 cm
☐ A = 10 cm, B = 15 cm, C = 25 cm
☐ A = 18 cm, B = 27 cm, C = 45 cm
☐ A = 20 cm, B = 30 cm, C = 50 cm

Figure 3. Assessment Instrument Draft

3.3. Development

The initial draft produced in the Design stage was validated by two mathematics education lecturers to determine its validity before being revised into the final product. Validation was carried out separately for the teaching module, student worksheet, and assessment instrument using the aspects and instruments described in the Method section, and the results were analyzed using Gregory's validity formula. Based on the validators' quantitative scores and qualitative comments, each component was then revised to produce the final version of the STEM-PjBL learning tool. The validation and revision results for each component are presented below.

3.3.1. Teaching Module

The teaching module draft was reviewed by two validators using a six-aspect validity instrument (content, presentation, language, learning activities, STEM, and Engineering Design Process). Each item was rated on a 4-point scale and analyzed with Gregory's validity formula, as described in the Method section. The results of the expert validation are shown in Table 4.

Table 4. Teaching Module Validation

Aspect	Items	A	B	C	D	V	Category
Content	4	0	0	0	4	1	High validity
Presentation	5	0	0	0	5	1	High validity
Language	3	0	0	0	3	1	High validity
Learning Activities	7	0	0	0	7	1	High validity
STEM	4	0	0	0	4	1	High validity
Engineering Design Process	6	0	0	0	6	1	High validity
Overall	29	0	0	0	29	1	High validity

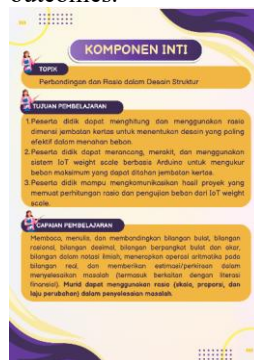
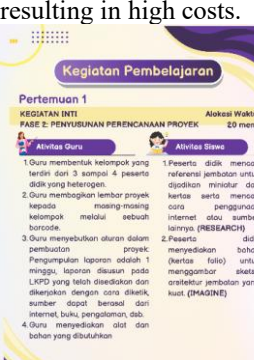
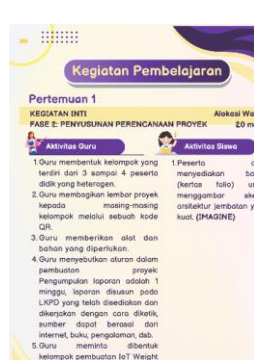
All six aspects of the teaching module reached a validity index of 1.00, placing the instrument in the high-validity category with no items falling into the weak cells of the contingency table. A comparable digital project-based-learning module tested with the same Gregory technique reached an index of 0.90, likewise in the very high category [25], which points to a broader pattern: modules built directly from clearly defined learning objectives and a structured engineering-design-process syntax tend to be judged highly relevant by experts, even when qualitative refinements are still needed.

Despite the high validity index, the two validators provided four qualitative notes that were followed up in the revision stage. A comparison of selected sections of the module before and after revision is presented in Table 5.

Table 5. Comparison of the Teaching Module Before and After Revision

No.	Component	Before Revision	After Revision
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STEM-IoT Integration in Paper Bridge Projects: Development of a Learning Tool for Teaching Ratio and Proportion (Karina Surya Eka Kusuma)

1	Learning and Objectives	Outcomes Learning	Learning outcomes did not refer to the newest 2025 Merdeka Curriculum.	Learning objectives were re-derived from the updated learning outcomes.
				
2	Guiding Questions		The guiding questions were not sufficiently engaging to stimulate students' curiosity.	Revised to be more contextual and engaging, thereby better stimulating students' curiosity.
				
3	IoT Building		Each small group was required to assemble its own IoT weight scale, resulting in high costs.	Assembled by one large group to reduce implementation costs.
				
4	Spelling		The word <i>menanyakan</i> (asking) was misspelled as <i>menyakan</i> .	The typo was corrected to <i>menanyakan</i> ("asking").



The first revision follows directly from the Ministry's 2025/2026 update to the CP [13], which requires teaching modules to re-derive their learning objectives from the revised standard rather than the previous one. The second revision, sharpening the guiding questions, aligns with findings that a well-designed driving question is what sustains inquiry and motivation throughout a project, particularly in under-resourced educational settings where engagement cannot be taken for granted [34]. The third revision, consolidating IoT construction into larger groups, reflects a broader concern in low-cost STEM hardware research: Arduino-based platforms remain the cheapest viable option for classroom electronics, yet even their modest per-unit cost becomes a real constraint once every small group is expected to build its own device, which is precisely why low-cost STEM frameworks are designed around shared or scaled deployment rather than one-kit-per-student models [33]. The fourth revision was a direct editorial correction.

3.3.2. Student Worksheet

The student worksheet draft was validated on four aspects: content, presentation, language, and graphical aspect. Table 6 presents the validation of the student worksheet.

Table 6. Student Worksheet Validation

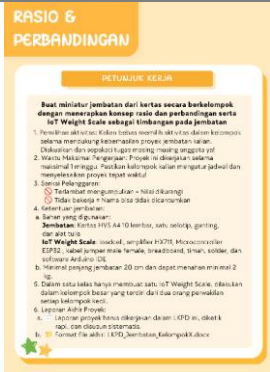
Aspect	Items	A	B	C	D	V	Category
Content	4	0	0	0	4	1	High validity
Presentation	7	0	0	0	7	1	High validity
Language	4	0	0	0	4	1	High validity
Graphical Aspect	5	0	0	0	5	1	High validity
Overall	20	0	0	0	20	1	High validity

All four aspects again reached a validity index of 1.00. This mirrors findings from another LKPD validated on the same four aspects using the Gregory technique, where validity testing on content, presentation, language, and graphical aspects reached a very high category with an average score of 1.00 [15], suggesting that worksheets built around a clearly staged activity structure (in this case, the six EDP phases) tend to be judged as highly relevant by experts.

Although the worksheet achieved a perfect validity index, the validators also provided several suggestions to improve its quality further. A total of five revision points were identified, all of which were incorporated into the final version of the worksheet. The revisions are presented in Table 7.

Table 7. Comparison of the Student Worksheet Before and After Revision

No.	Component	Before Revision	After Revision
1	Instruction	The instructions needed to be more specific, were written in uppercase, and were placed before the Ask phase.	Instructions were clarified, reformatted, and moved before the Imagine phase.

			
2	Ask Phase	The Ask phase included only an image of the collapsed bridge.	A QR video of the bridge collapse was added to provide a more engaging project trigger.
			
3	Research Phase	The Research phase did not include activities for learning the concepts of ratio and proportion.	Activities were added to help students explore and understand the concepts of ratio and proportion.
			
4	Plan Phase	The Plan phase focused only on planning the paper bridge and IoT weight scale.	An activity for identifying the required materials and tools was added before the planning stage to improve students' understanding.

5	Create	The Create phase instructed students to attach the completed paper bridge.	The instruction was revised to require a photograph of the completed paper bridge.

Revisions 1 and 5 both concern instructional clarity, which recent classroom research links to reduced cognitive load and stronger task engagement: clearer instructions ease the processing burden on learners and support their sense of competence, which in turn sustains motivation during a task [21]. Revision 2, adding a video stimulus, follows a similar logic to studies showing that instructional video used within a problem-based approach improves students' scientific attitude and learning outcomes, since a short, concrete visual anchor gives students something tangible to question before they are asked to design a solution [27]. Revisions 3 and 4 concern the sequencing and scaffolding of the engineering design process itself; the driving-question framework this study draws on treats guided exploration, collaborative activity, and scaffolded tasks as elements distinct from, but essential to supporting, the driving question [34], which is consistent with moving procedural instructions ahead of the Plan phase and adding a concept-learning activity in Research so that students engage with both content and procedure before constructing their design.

3.3.3. Assessment Instrument

The assessment instrument draft was validated on three aspects: content suitability, construction, and readability. The results of the expert validation are presented in Table 8.

Table 8. Assessment Instrument Validation

Aspect	Items	A	B	C	D	V	Category
Content	5	0	0	0	5	1	High validity
Construction	3	0	0	0	3	1	High validity
Readability	9	0	0	0	9	1	High validity
Overall	17	0	0	0	17	1	High validity

All three aspects reached a validity index of 1.00. A comparable Gregory-based validation of a critical-thinking test instrument covering knowledge, language, and construction aspects likewise reported a very high overall validity category [18], indicating that assessment items built directly from clearly stated

indicators and learning objectives tend to be judged highly relevant even when minor surface-level errors remain.

Despite receiving a perfect validity index, the worksheet was further refined based on recommendations from the expert validators. The revisions made to the final version are presented in Table 9.

Table 9. Comparison of the Assessment Instrument Before and After Revision

No	Component	Before Revision	After Revision																																																																																																												
1	Language Standardization	Incorrect capitalization and missing period. ANGKET PENILAIAN GURU Nama Kelompok : Anggota Kelompok : 1. 2. 3. 4. Petunjuk : Beri centang (✓) pada setiap nomor sesuai dengan kriteria yang dinilai berdasarkan kinerja kelompok (1=sangat kurang, 2=kurang, 3=cukup, 4=baik, 5=sangat baik). <table><tr><th rowspan="2">NO</th><th rowspan="2">KRITERIA PENILAIAN</th><th colspan="5">SKOR</th></tr><tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><td>1.</td><td>Kesesuaian Desain Jembatan dengan prinsip Matematika dan Teknik.]</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>2.</td><td>Kreativitas dalam pemilihan dan pengolahan bahan kertas.</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>3.</td><td>Kerja sama dan komunikasi antar anggota kelompok.</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>4.</td><td>Efektivitas waktu dan manajemen proyek.</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>5.</td><td>Kekuatan struktur jembatan saat uji beban minimal 2 kg.</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>6.</td><td>Kualitas presentasi hasil dan penjelasan konsep.</td><td></td><td></td><td></td><td></td><td></td></tr></table>	NO	KRITERIA PENILAIAN	SKOR					1	2	3	4	5	1.	Kesesuaian Desain Jembatan dengan prinsip Matematika dan Teknik.]						2.	Kreativitas dalam pemilihan dan pengolahan bahan kertas.						3.	Kerja sama dan komunikasi antar anggota kelompok.						4.	Efektivitas waktu dan manajemen proyek.						5.	Kekuatan struktur jembatan saat uji beban minimal 2 kg.						6.	Kualitas presentasi hasil dan penjelasan konsep.						The capitalization was corrected, and a period was added. ANGKET PENILAIAN GURU Nama Kelompok : Anggota Kelompok : 1. 2. 3. 4. Petunjuk : Beri centang (✓) pada setiap nomor sesuai dengan kriteria yang dinilai berdasarkan kinerja kelompok (1=sangat kurang, 2=kurang, 3=cukup, 4=baik, 5=sangat baik). <table><tr><th rowspan="2">NO</th><th rowspan="2">KRITERIA PENILAIAN</th><th colspan="5">SKOR</th></tr><tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr><tr><td>1.</td><td>Kesesuaian Desain Jembatan dengan prinsip Matematika dan Teknik</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>2.</td><td>Kreativitas dalam pemilihan dan pengolahan bahan kertas</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>3.</td><td>Kerja sama dan Komunikasi antar anggota kelompok</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>4.</td><td>Efektivitas waktu dan manajemen proyek</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>5.</td><td>Kekuatan struktur jembatan saat uji beban minimal 2 kg.</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>6.</td><td>Kualitas presentasi hasil dan penjelasan konsep</td><td></td><td></td><td></td><td></td><td></td></tr></table>	NO	KRITERIA PENILAIAN	SKOR					1	2	3	4	5	1.	Kesesuaian Desain Jembatan dengan prinsip Matematika dan Teknik						2.	Kreativitas dalam pemilihan dan pengolahan bahan kertas						3.	Kerja sama dan Komunikasi antar anggota kelompok						4.	Efektivitas waktu dan manajemen proyek						5.	Kekuatan struktur jembatan saat uji beban minimal 2 kg.						6.	Kualitas presentasi hasil dan penjelasan konsep					
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Although this revision did not change the validity index, using standardized language remains important for the practical use of the instrument. Replacing non-standard words with their standard forms improves clarity, reduces the cognitive effort required to interpret assessment items, and supports more accurate task engagement [21].

4. CONCLUSION AND SUGGESTIONS

4.1. Conclusion

This study developed a STEM-PjBL learning tool, consisting of a teaching module, student worksheet, and assessment instrument, that integrates a paper bridge project with a student-built IoT weight scale to teach ratio and proportion to seventh-grade students. Guided by the Analysis, Design, and Development stages of the ADDIE model, the tool was designed around a six-phase Engineering Design Process and evaluated for validity by two mathematics education experts using Gregory's formula. All three components reached a validity index of 1.00 on every rated aspect, indicating high validity, and the qualitative notes from the validators, concerning curriculum alignment, question design, resource feasibility, and language accuracy, were fully incorporated into the final revision. These findings answer the study's aim: a valid STEM-PjBL learning tool that authentically integrates mathematical reasoning with a student-built measurement instrument can be produced, addressing the previously identified gap in which mathematics and technology have received limited emphasis within integrated STEM practice, and in which IoT-based instruments have rarely been applied to ratio and proportion learning specifically. However, this conclusion is bounded by the scope of the study, which was limited to expert-judgment validity within the Development stage; the tool's practicality and effectiveness in an actual classroom setting have not yet been examined

4.2. Suggestions

Because this study was limited to the Analysis, Design, and Development stages of the ADDIE model and assessed only validity through expert judgment, future research should extend the remaining Implementation and Evaluation stages by trialing the learning tool in an actual seventh-grade classroom. Such studies should examine its practicality through teacher and student responses as well as its effectiveness in improving students' learning outcomes in ratio and proportion. Building on these findings, future researchers are also encouraged to adapt the paper bridge-IoT weight scale model to other mathematical topics or grade levels and to further explore the integration of student-built measurement instruments into other underrepresented areas of STEM-based mathematics instruction.

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