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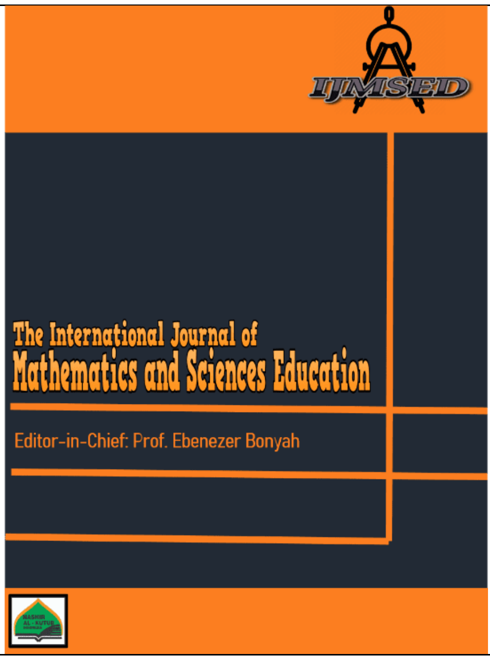

Microsoft excel-assisted project-based learning for students' mathematical representation: A classroom action research on data presentation

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Microsoft excel-assisted project-based learning for students' mathematical representation: A classroom action research on data presentation

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Mathematical representation ability—the capacity to express mathematical ideas through tables, diagrams, symbols, and verbal explanations—is a key competency in mathematics learning. However, Indonesian junior secondary students continue to experience difficulties, particularly in data presentation. This study investigated the effectiveness of Microsoft Excel-assisted Project-Based Learning (PjBL) in improving the mathematical representation ability of 31 seventh-grade students at Madrasah Tsanawiyah Negeri 28 Jakarta, Indonesia. A Classroom Action Research design was conducted in two cycles, each involving planning, action, observation, and reflection. Data were collected through representation-ability tests, classroom observations, semi-structured interviews, and documentation, and analysed using the Miles and Huberman interactive model with source triangulation. Results showed that the mean representation score increased from 65.16 in Cycle I to 78.39 in Cycle II, while the proportion of students achieving the minimum mastery criterion rose from 48.39% to 87.09%. Improvements occurred across all six representation indicators, including presenting data in tables, constructing diagrams, interpreting representations, explaining data, comparing forms of data presentation, and selecting appropriate representations. These findings suggest that integrating PjBL with Microsoft Excel promotes active, contextual, and technology-supported learning that strengthens students' mathematical representation ability. However, because the study involved a single class of 31 students, the findings represent classroom-specific evidence and should not be statistically generalised to broader student populations.

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1. Introduction

Equipping students with the mathematical competencies demanded by twenty-first-century learning is a recurring concern in mathematics education research, and mathematical representation ability sits at the centre of that concern. Representation is one of the process standards through which students come to understand and communicate mathematical ideas, and it functions as a tool for building understanding, communicating reasoning, and solving problems (Goldin, 2014). Complementing this functional account, Duval's (2006) theory of registers of semiotic representation explains why representation is cognitively demanding in the first place: mathematical objects can only be accessed through signs, and the same object can be expressed in several distinct registers, tabular, graphical, symbolic, and verbal, none of which is identical to the mathematical object itself. A related theoretical perspective, Vergnaud's theory of conceptual fields, further clarifies that a mathematical concept only becomes meaningful to a learner through the situations in which it is used, the operational invariants the learner recognises, and the representations used to express it, reinforcing that representation cannot be taught as a technique detached from meaningful problem situations (Alfaro-Carvajal & Fonseca-Castro, 2016). Learning therefore depends on students being able to convert an idea from one register to another, a process Duval identifies as a persistent source of difficulty rather than a by-product of poor instruction alone.

A recent systematic review of Scopus-indexed research on mathematical representation ability confirms that this competency remains an active and unresolved area of inquiry, with converting between visual and symbolic forms singled out as one of the most frequently reported student weaknesses across studies (Putra et al., 2023). Individual intervention studies within this broader trend illustrate the same pattern: learning trajectories built explicitly around algebraic representation have been shown to support students' representational reasoning in secondary mathematics (Khairunnisak et al., 2021), challenge-based learning delivered through mobile applications has improved students' representation ability relative to conventional instruction (Susilawati, 2020), and structured learning on topics such as ellipses has been linked to measurable gains in students' mathematical communication skills, a competency closely related to representation (Tong et al., 2021), a pattern also evident in instructional models combining dynamic geometry software with structured learning cycles to strengthen students' mathematical communication (Mustikaningsih et al., 2025). Contextual and modelling-based approaches more generally have also been associated with improved motivation and confidence in mathematical problem-solving, including in university-level differential equations instruction (Spooner, 2024), reinforcing that the difficulty lies less in the mathematics content itself than in how students are supported to engage with and translate it. This difficulty is not confined to mathematics in the abstract: it is especially visible in statistics instruction, where students must read, interpret, and produce graphs from raw data. Systematic reviews of statistical and data literacy in K-12 STEM education report that graph and chart interpretation is one of the most heavily studied yet persistently weak competencies among school students internationally (Friedrich et al., 2024; Schreiter et al., 2024), a pattern that also holds for prospective teachers, whose own graph- and table-interpretation performance is often only moderate (Hamerská et al., 2025). Even at the university level, students continue to struggle specifically with extrapolating beyond the data given in a graph, regardless of which solution method they use (Bragdon et al., 2018), which suggests that the difficulty observed in Indonesian junior secondary classrooms is part of a broader, internationally documented pattern rather than a local anomaly.

In the Indonesian context specifically, statistical literacy, of which mathematical representation is a core component, has been the subject of a growing but still uneven body of research, with a systematic review noting that most existing studies are qualitative and locally scoped, and calling explicitly for more classroom-based intervention research using collaborative, activity-based approaches (Wijayanti & Juandi, 2024). At the classroom level, teachers commonly report that instruction on data presentation remains procedural: students are shown how to construct a bar chart or a pie chart, but rarely learn why one representation is more appropriate than another for a given dataset, or how to translate between representations flexibly. Consistent with this, students in the present study's target class demonstrated difficulty converting raw data into suitable visual forms and could not reliably select an appropriate representation for a given dataset, suggesting that instruction had emphasised procedural execution over conceptual understanding of representation itself. This impression was corroborated by a pre-cycle diagnostic check administered before Cycle I began, in which [ISI: cantumkan persentase/skor siswa yang belum mampu mengonversi data mentah ke bentuk representasi yang sesuai, mis. "only 8 of 31 students (25.8%) could correctly convert the sample dataset into an appropriate table or chart, providing an empirical baseline against which the Cycle I-to-Cycle II improvement can be judged, rather than relying on narrative impression alone.

One explanation for this pattern lies in prevailing instructional practice. When mathematics instruction remains teacher-centred, with the teacher demonstrating a fixed procedure and students largely reproducing it, students have few opportunities to construct, compare, and justify their own representations, precisely the activities that research identifies as necessary for representational competence to develop. This concern is consistent with reviews of differentiated instruction showing that conventional, teacher-directed delivery leaves comparatively little room for the kind of active, student-constructed engagement that learners need in order to keep progressing (Ziernwald et al., 2022; Smale-Jacobse et al., 2019). Related classroom research further links weak representation ability to low learner autonomy: students who rarely collaborate with peers or who lack the confidence to present their own solutions tend to fall back on imitating the teacher's steps rather than reasoning through the representation task themselves, a pattern also reflected in cooperative-learning research showing that peer acceptance and group-based engagement are important preconditions for students' willingness to reason through, rather than merely copy, a mathematical solution (Klang et al., 2021). Addressing this gap therefore requires not only more technology in the classroom, but a pedagogical model that structures students' engagement with data around meaningful, self-directed tasks.

Project-Based Learning (PjBL) is one such model. First articulated as a comprehensive approach that engages students in the investigation of authentic problems (Blumenfeld et al., 1991), PjBL has since been consistently associated with the development of the collaboration, critical thinking, and self-directed inquiry skills that twenty-first-century curricula seek to cultivate (Bell, 2010). In mathematics classrooms specifically, PjBL has been shown to significantly strengthen collaborative learning, problem-solving, critical thinking, and students' attitudes toward mathematics (Rehman et al., 2024; Balta, 2024), and it has produced measurable gains in student achievement in elementary mathematics settings when implemented as a structured, teacher-guided project sequence rather than an unstructured activity (Lazić et al., 2021). The relationship between PjBL and mathematics achievement has also been shown to operate partly through improved attitudes toward cooperation and heightened motivation, indicating that PjBL's benefits are mediated by affective as well as cognitive changes in how students engage with mathematical tasks (Qi et al., 2025). A recent systematic review of problem-based learning in K-12 mathematics similarly concludes that digitally integrated PjBL models are increasingly the dominant and most frequently reported variant in the literature, ahead of purely offline implementations (Ayari et al., 2025). Similarly, a systematic review focused specifically on PjBL in mathematics classrooms links the model to gains in students' mathematical creative thinking that are mediated by their level of self-regulated learning (Nurfaidah et al., 2023). Because PjBL requires students to produce a tangible product, in this study, a data presentation, it aligns naturally with the demand that students generate, compare, and justify multiple representations of the same dataset, rather than merely reproduce a single procedure demonstrated by the teacher.

Realising this alignment in practice, however, depends on the tools available for producing representations. Spreadsheet software has repeatedly been shown to support exactly this kind of representational work. Excel-based active learning activities have been found to increase student engagement and course evaluations in technical subjects that depend on translating raw data into usable form (Saha, 2022), and, within mathematics education specifically, VBA-Microsoft Excel-assisted Realistic Mathematics Education has been shown to support students' mathematical abstraction ability by allowing them to manipulate and visualise mathematical objects interactively (Fitriani, Suryadi, & Darhim, 2018). Broader reviews of digital technology in mathematics education likewise report consistent, if uneven, gains in engagement and conceptual understanding when spreadsheet and other digital tools are integrated purposefully into lesson design, rather than used as an add-on to conventional instruction (Engelbrecht & Borba, 2024; Hidayat & Firmanti, 2024; Hidayat et al., 2023), a pattern corroborated by structural equation modelling evidence linking technology integration and learner engagement directly to students' mathematical problem-solving ability (Gyenyn et al., 2026), the broader pedagogical tradition from which Excel-based approaches to representation, including the present study, draw, which show steadily growing Scopus-indexed research attention to technology-integrated variants of this approach (Phan et al., 2022). Realising these gains in practice, however, also depends on teachers' capacity to integrate technology, pedagogy, and content knowledge in a coherent way,the construct captured by the TPACK framework, since studies of TPACK in mathematics education consistently identify limited technological-pedagogical integration, rather than lack of access to technology per se, as the more binding constraint on effective technology-assisted instruction (Kholid et al., 2023; Hidayat & Chao, 2024).

Taken together, the literature establishes three things reasonably firmly: that mathematical representation ability is a persistent area of difficulty with a well-characterised cognitive basis (Duval, 2006; Goldin, 2014; Putra et al., 2023); that difficulties with graph and data interpretation specifically are widespread across statistics and STEM education internationally as well as in Indonesia (Bragdon et al., 2018; Friedrich et al., 2024; Wijayanti & Juandi, 2024); and that Project-Based Learning and spreadsheet-based technology each independently support the kind of active, representation-rich engagement that this competency requires (Blumenfeld et al., 1991; Fitriani et al., 2018; Rehman et al., 2024; Saha, 2022). What remains comparatively unexamined is how these two elements function when combined in a single, classroom-embedded intervention aimed specifically at representation ability in the data presentation strand of junior secondary mathematics, as distinct from studies that examine PjBL or educational technology on general achievement outcomes. This study addresses that gap by asking: to what extent can Microsoft Excel-assisted Project-Based Learning improve the mathematical representation ability of seventh-grade students on the topic of data presentation, both overall and across its constituent indicators? The novelty of this study lies specifically in applying Excel-assisted PjBL to the data-presentation strand of statistics, a representational context that, unlike the general achievement outcomes examined in prior PjBL and educational-technology research, has not previously been the direct target of a classroom-embedded intervention.

2. 2. Methods

2.1 Research Design

This study used a Classroom Action Research (CAR) design, following the widely used four-stage cyclical model of planning, action, observation, and reflection (Mertler, 2021), implemented across two cycles. CAR was selected because it allows an intervention to be adjusted iteratively in response to evidence gathered directly from the researcher's own classroom, a methodological logic that has been used productively elsewhere to improve specific, identifiable weaknesses in mathematics instruction through successive, evidence-informed cycles of practice pursued within professional learning communities of mathematics teachers (Bondurant, 2024). This same iterative logic underlies design-based classroom action research, which reframes teachers as active designers of their own instructional strategies rather than passive implementers of externally developed methods (Yundayani & Alghadari, 2024). Each cycle in the present study targeted the same six indicators of mathematical representation ability, with the reflection stage of Cycle I directly informing the revisions made to the Excel-assisted project tasks used in Cycle II.

2.2 Participants

The participants were 31 seventh-grade students in class VII.C at Madrasah Tsanawiyah Negeri 28 Jakarta, Indonesia, selected because this class had been identified, through prior formative assessment, as showing weak performance on data-presentation tasks relative to parallel classes. All 31 students participated in both cycles of the intervention. A Classroom Action Research design, rather than a quasi-experimental design with a comparison class, was chosen because the primary aim was to iteratively refine the Excel-assisted PjBL intervention itself in response to evidence gathered directly from this classroom, not to isolate a causal treatment effect against a control group. Consequently, the "improvement" reported in this study reflects the joint effect of the intervention and its cyclical refinement between Cycle I and Cycle II, and should not be interpreted as the effect of a fixed, unmodified intervention delivered once. As participants were minors in a compulsory classroom setting, ethical clearance was obtained from [ISI: nama institusi/komite etik], and informed consent/assent was obtained from parents or guardians and from students themselves prior to data collection.

2.3 Data Collection Instruments

Four data collection techniques were used: (1) a mathematical representation ability test, administered individually to each student (not scored at the group level) at the end of each cycle and constructed around six indicators, presenting data in tabular form, converting data into diagrams, interpreting information from tables or diagrams, explaining the meaning of data, comparing different forms of data presentation, and selecting the most appropriate form of presentation for a given dataset, derived from the representation framework of Goldin (2014) and the registers of semiotic representation described by Duval (2006); (2) classroom observation of student engagement and project activity during each cycle; (3) semi-structured interviews with 4 to probe their reasoning behind chosen representations; and (4) documentation of students' project artefacts, including their Excel-generated tables, charts, and graphs. Because scoring an open-ended representation task necessarily involves rater judgement, the test was scored using an analytic rubric with descriptors for each indicator, consistent with recommendations that rubric-based assessment of complex, constructed-response tasks be analytic and indicator-specific in order to support reliable and meaningful scoring (Jonsson & Svingby, 2007). Prior to use, the content validity of the rubric and test items was established through expert judgement by two mathematics education experts.

2.4 Procedure

In both cycles, the Project-Based Learning sequence followed the same overall structure: the teacher posed an authentic, contextual data-collection task (for example, gathering and presenting data on classmates' daily habits); students worked in small groups of 0.34, to collect raw data, and then used Microsoft Excel to organise the data into a frequency table before selecting and constructing an appropriate chart (bar, line, or pie) to represent it; groups then presented and justified their choice of representation to the class, after which the teacher facilitated a whole-class discussion comparing the representations produced by different groups. Working in small, collaborative groups was intended to give students the kind of peer-supported opportunity to construct, compare, and justify representations that has been associated with improved mathematics learning outcomes in cooperative-learning settings (Sofroniou & Poutos, 2016; Klang, Karlsson, Kilborn, Eriksson, & Karlberg, 2021). Cycle II retained this structure but incorporated revisions identified during the Cycle I reflection stage, including more explicit teacher scaffolding on choosing between chart types and additional guided practice with Excel's charting tools, informed by classroom observation of where students had struggled in Cycle I.

2.5 Data Analysis

Quantitative test scores were analysed descriptively, comparing the mean score, the percentage of students reaching the minimum mastery criterion, and the percentage of students meeting each of the six representation indicators, between Cycle I and Cycle II. Qualitative data from observations, interviews, and documentation were analysed using the interactive model of Miles and Huberman, comprising data reduction, data display, and conclusion drawing/verification, applied iteratively within and across the two cycles. To strengthen the credibility of the qualitative findings, data from the three sources — observation, interview, and documentation — were triangulated, consistent with the broader methodological principle that triangulation across data sources is one of the more dependable strategies for establishing the trustworthiness of classroom-based qualitative findings (Morgan, 2024). To assess whether the observed improvement between Cycle I and Cycle II was statistically significant rather than attributable to ordinary between-cycle variation, a paired-samples t-test (or, if the distribution of scores departed from normality, a Wilcoxon signed-rank test) was additionally conducted on students' Cycle I and Cycle II scores, with effect size reported as Cohen's d.

2.6 Ethical Clearence

This study was conducted in accordance with the ethical principles for research involving human participants, including the protection of minors in an educational setting. As the participants were seventh-grade students (minors) at Madrasah Tsanawiyah Negeri 28 Jakarta, ethical clearance and written research permission were obtained from the school principal prior to the commencement of Cycle I. Prior to data collection, the purpose, procedures, and voluntary nature of participation were explained to the students and their parents/guardians, and informed consent was obtained from parents or guardians together with informed assent from the students themselves. Participants were assured that their participation, or non-participation, would not affect their academic standing, and that all data collected (test scores, observation notes, and interview responses) would be used solely for research purposes and reported anonymously. No physical, psychological, or social risks beyond those of normal classroom instruction were involved in this study, as the intervention was embedded within the regular mathematics curriculum.

3. Results and Discussion

3.1 Cycle I

3.1.1 Planning

Planning for Cycle I began with a pre-cycle diagnostic check administered one week before the first session, in which students were asked to convert a short raw dataset (classmates' shoe sizes) into an appropriate table and chart without teacher guidance; only 9 of the 31 students (29.0%) produced a fully correct representation, confirming the difficulty identified through prior formative assessment. Based on this diagnosis, the researcher-teacher, in consultation with a peer mathematics teacher and the school's academic supervisor, developed a lesson plan (RPP) for a four-meeting Excel-assisted Project-Based Learning sequence built around an authentic, contextual data-presentation task: collecting and presenting data on classmates' daily habits (screen time and sleep duration). The planning stage produced four artefacts used throughout Cycle I: (1) the lesson plan detailing learning objectives, activities, and time allocation for each meeting; (2) a structured student worksheet guiding data collection, Excel data entry, and chart construction; (3) the six-indicator mathematical representation ability test together with its analytic rubric, whose content validity was established through expert judgement by two mathematics education lecturers prior to use (Section 2.3); and (4) observation and interview guides used to record student engagement and to probe students' reasoning during and after the cycle. Six working groups of five to six students each were formed by the teacher, balancing each group's composition across students' pre-cycle diagnostic results so that no group consisted solely of students who had struggled on the diagnostic check.

3.1.2 Action

Cycle I was carried out over four meetings of 2 × 40 minutes each, scheduled across two weeks. In Meeting 1, the teacher introduced the data-presentation task and modelled, using a worked example, how to organise raw survey responses into a frequency table in Microsoft Excel; each group then collected raw data on classmates' daily screen-time and sleep duration using a paper tally sheet. In Meeting 2, groups entered their raw data into Excel, used basic functions (sum, countif, and average) to compute frequencies and summary statistics, and began organising the data into a frequency table. In Meeting 3, groups selected a chart type (bar, line, or pie) using Excel's Insert Chart feature, formatted

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their chosen chart, and prepared a short justification for why that chart type suited their dataset. In Meeting 4, each group presented and justified its choice of representation to the class, after which the teacher facilitated a whole-class discussion comparing the representations produced by the six groups and highlighting cases where two groups had represented similar data differently. The mathematical representation ability test was administered individually to all 31 students at the end of Meeting 4.

3.1.3 Observation and Evaluation

Classroom observation, guided by a structured observation sheet covering engagement, on-task collaboration, and use of Excel features, was conducted concurrently with the action stage by the teacher-researcher and a peer observer. Observation notes indicated high engagement during the hands-on Excel meetings (Meetings 2 and 3) but more uneven participation during Meeting 1's data-collection activity, where two of the six groups required additional teacher prompting to begin recording data systematically. Several groups were observed hesitating between a bar chart and a pie chart when their dataset had more than five categories, often defaulting to whichever chart type they had used most recently rather than reasoning about which best suited the data.

At the end of Cycle I, the representation-ability test yielded a class mean score of 65.16, with 48.39% of students (15 of 31) reaching the minimum mastery criterion (Table 1). Per-indicator results (Table 2) showed the strongest Cycle I performance on presenting data in tabular form (78%) and converting data into diagrams (72%), consistent with the direct, hands-on support Excel provided for these two tasks, and the weakest performance on comparing different forms of data presentation (58%) and selecting the most appropriate form of presentation (56%), mirroring the chart-selection hesitation noted during observation.

3.1.4 Reflection

The Cycle I reflection meeting, held with the peer observer immediately after Meeting 4, triangulated the test results, observation notes, and brief post-test interviews with six purposively selected students (one high-, one middle-, and one low-scoring student from two groups). Three recurring difficulties emerged. First, students could construct a chart correctly once a chart type had been chosen, but lacked an explicit basis for choosing between chart types, often citing “this one looked nicer” rather than a property of the data. Second, students found it difficult to compare two different representations of the same dataset and to say which conveyed the information more clearly. Third, two groups had confused categorical and numerical variables when labelling their chart axes, which the researcher judged to be a contributing factor behind the lower interpreting and explaining scores.

These findings directly informed three revisions carried into Cycle II: (1) an explicit 15-minute mini-lesson at the start of Meeting 1 introducing a simple decision guide for matching chart type to data type (categorical-few-categories, categorical-many-categories, or trend-over-time); (2) additional guided practice in which each group compared two teacher-provided representations of the same dataset before working on their own; and (3) a revised worksheet that required groups to label which variable was categorical and which was numerical before entering data into Excel.

3.2 Cycle II

3.2.1 Planning

Informed by the Cycle I reflection, the lesson plan for Cycle II retained the same four-meeting structure, the same six working groups, and the same data-presentation task format so that any improvement between cycles could be attributed to the revised scaffolding rather than to a different task or instrument. The worksheet was revised to include the categorical/numerical labelling step and the chart-type decision guide identified above, and a new short comparison activity was added to Meeting 3. The representation-ability test and its rubric were not altered from Cycle I.

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3.2.2 Action

Cycle II followed the same overall Project-Based Learning sequence as Cycle I (Section 3.1.2) across four meetings of 2 × 40 minutes, using a new dataset (classmates' weekly pocket-money and spending categories) so that students could not simply reproduce their Cycle I charts from memory. Meeting 1 opened with the 15-minute chart-selection mini-lesson before data collection began. In Meeting 3, before constructing their own chart, each group first examined two teacher-provided representations of a sample dataset, discussed in their group which representation was clearer and why, and recorded their reasoning on the worksheet before proceeding to their own data. Meetings 2 and 4 otherwise followed the same format as in Cycle I, and the representation-ability test was again administered individually to all 31 students at the end of Meeting 4.

3.2.3 Observation and Evaluation

Observation during Cycle II indicated markedly less hesitation during chart-type selection: groups were observed referring back to the decision guide and explicitly stating a data-based reason for their chosen chart type (for example, “we used a pie chart because spending categories add up to a whole”) rather than relying on visual preference alone. The added comparison activity in Meeting 3 also generated more substantive group discussion, with several groups debating which of the two provided representations communicated the data more clearly before returning to their own dataset.

At the end of Cycle II, the class mean score rose to 78.39, with 87.09% of students (27 of 31) reaching the minimum mastery criterion (Table 1), an improvement over Cycle I. Gains were observed across all six indicators (Table 2), with the largest relative gains on the two previously weakest indicators: comparing different forms of data presentation (58% to 75%) and selecting the most appropriate form of presentation (56% to 75%).

3.2.4 Reflection

Reflection at the end of Cycle II, again triangulating test results, observation notes, and follow-up interviews with the same six students, indicated that the revised scaffolding narrowed, but did not fully close, the gap on the two hardest indicators: comparing and selecting still showed the smallest absolute Cycle II scores of the six indicators, even though they had improved the most in relative terms. Interviewed students who had previously defaulted to visual preference now consistently referenced the decision guide when explaining their chart choice, but two of the six interviewed students still expressed uncertainty when a dataset did not clearly fit any single category in the guide, suggesting that a two-cycle intervention narrows this specific difficulty without eliminating it entirely.

As discussed further in Section 3.4, this residual gap is consistent both with Duval's (2006) account of register conversion as cognitively demanding and with a possible ceiling/floor effect, since the two strongest indicators had comparatively less room to improve. Because measurable improvement was achieved across all six indicators and the proportion of students reaching the mastery criterion rose to 87.09%, the researcher judged the research question to have been substantively answered and concluded the cyclical intervention after two cycles, consistent with common practice in Classroom Action Research once the targeted improvement has been demonstrated (Mertler, 2021).

3.3 Overall Improvement in Mathematical Representation Ability

The mathematical representation ability test showed a clear improvement between the two cycles. The class mean rose from 65.16 in Cycle I to 78.39 in Cycle II, while the percentage of students reaching the minimum mastery criterion rose from 48.39% to 87.09%. Table 1 summarises these overall results.

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Table 1
Comparison of Mean Scores and Mastery Attainment across Cycle I and Cycle II

Measure	Cycle I	Cycle II
Class mean score	65.16	78.39
Students reaching mastery criterion	48.39%	87.09%

This pattern of improvement is consistent with prior classroom-based evidence that Project-Based Learning, when implemented in mathematics classrooms, produces measurable gains in engagement, collaborative problem-solving, and attitudes toward mathematics that plausibly underlie improved performance on subsequent assessment (Rehman et al., 2024), and it is consistent with evidence that PjBL's effect on mathematics achievement operates partly through improved student motivation and cooperation. The magnitude of improvement observed here is also broadly comparable to that reported for VBA-Microsoft Excel-assisted Realistic Mathematics Education, where interactive, technology-mediated tasks were similarly associated with gains in students' mathematical abstraction ability relative to more procedural instruction (Fitriani et al., 2018).

3.4 Improvement across Representation Indicators

Gains were observed across all six indicators of mathematical representation ability assessed in this study, as summarised in Table 2. Percentages in Table 2 represent the proportion of the 31 students meeting the scoring-rubric criterion for that indicator, not a mean indicator score.

Table 2
Percentage of Students Meeting Each Representation Indicator, Cycle I and Cycle II

Indicator	Cycle I	Cycle II
Presenting data in tabular form	78%	92%
Converting data into diagrams	72%	88%
Interpreting information from tables or diagrams	64%	80%
Explaining the meaning of data	61%	78%
Comparing different forms of data presentation	58%	75%
Selecting the most appropriate form of presentation	56%	75%

Two patterns in Table 2 are worth discussing in relation to the literature. First, the two indicators showing the lowest performance in both cycles, comparing different forms of data presentation (58% to 75%) and selecting the most appropriate form of presentation (56% to 75%), are precisely the indicators that require students to reason across representational registers rather than execute a single, well-rehearsed procedure. This is consistent with Duval's (2006) account of conversion between registers as a qualitatively harder cognitive operation than treatment within a single register, and it echoes findings that graph and chart interpretation remains one of the most persistently weak competencies in K-12 statistics education internationally (Friedrich et al., 2024; Schreiter et al., 2024), and that even prospective teachers show only moderate confidence and performance on graph and table interpretation tasks (Hamerská et al., 2025). That these two indicators improved the least, even as they still improved substantially, suggests that Excel-assisted PjBL narrows but does not fully close this well-documented representational gap within two short cycles. An alternative, complementary explanation is a ceiling/floor effect: the two strongest indicators, presenting data in tabular form and converting data into diagrams, already started highest in Cycle I (78% and 72%, respectively), leaving comparatively less room to improve than the two weakest indicators, which started substantially lower (58% and 56%). The comparatively smaller gains on the two hardest indicators should therefore be interpreted alongside this ceiling/floor pattern, not solely as evidence of unresolved cognitive difficulty.

Second, the indicators showing the strongest performance throughout, presenting data in tabular form and converting data into diagrams, are those most directly supported by Excel's built-in charting tools, which allow students to generate a table or chart quickly once the underlying data are organised, freeing cognitive resources for the more demanding tasks of interpretation and justification. This is consistent with evidence that in-class, Excel-based activities increase student engagement specifically because they let students focus on interpreting output rather than on the mechanics of construction (Saha, 2022), and with broader findings that digital tools integrated purposefully into mathematics lessons tend to support conceptual engagement rather than merely accelerate procedural work, provided teachers can integrate technology, pedagogy, and content coherently (Engelbrecht & Borba, 2024; Kholid et al., 2023; Jiménez Sierra et al., 2023; Priyanda et al., 2025).

3.5 The Role of Project-Based Learning and Collaboration

Classroom observation indicated that students were substantially more engaged during the project-based tasks than during the conventional instruction that preceded the intervention, particularly during the small-group data collection and Excel-charting stages. Interviews with selected students indicated that working collaboratively gave them more confidence in justifying their choice of representation to the class echoing evidence that cooperative, small-group structures in mathematics classrooms support both achievement and students' willingness to explain and defend their reasoning to peers (Sofroniou & Poutos, 2016; Klang et al., 2021), consistent also with two-cycle classroom action research evidence that cooperative, game-based learning models can strengthen junior secondary students' mathematical disposition alongside their learning outcomes (Mayangsari et al., 2025). This kind of active, self-directed engagement is also consistent with classic evidence that students' self-efficacy and use of self-regulatory learning strategies are closely tied to their classroom academic performance (Pintrich & De Groot, 1990), and it echoes more recent evidence that technology-enriched project-based tasks similarly foster self-regulated learning alongside gains in students' representational and spatial reasoning (Isharyadi et al., 2026), suggesting that the motivational shift observed alongside the PjBL tasks may itself have been part of the mechanism behind the representation-ability gains reported in Section 3.3 and 3.4. This is also consistent with systematic evidence that project-based learning in mathematics classrooms strengthens collaborative learning, critical thinking, and students' attitudes toward the subject as an integrated bundle of outcomes rather than as isolated gains (Rehman et al., 2024; Balta, 2024).

3.6 Limitations

This study has several limitations. First, as a Classroom Action Research conducted with a single class over two cycles, the findings describe what occurred in this specific classroom and cannot be generalised statistically to other schools or student populations; the design prioritises depth of understanding within one setting over generalisability across settings, a trade-off inherent to action research as a methodology. Second, the representation ability test, while built around an analytic rubric, was scored by the researcher-teacher, and no second, independent rater was used to establish inter-rater reliability; future studies would benefit from an independent scoring check. Third, the two-cycle timeframe, while sufficient to detect improvement, does not indicate whether the gains observed are durable over a longer period, particularly for the two lowest-performing indicators discussed in Section 3.4. Fourth, the researcher-teacher's own proficiency in TPACK and in Excel was not formally assessed or reported, which plausibly affects the fidelity and replicability of the intervention as implemented. Finally, because Excel and Project-Based Learning were combined as a single intervention package, this study cannot isolate the independent contribution of each component; a follow-up quasi-experimental design comparing PjBL alone, Excel-assisted instruction alone, and the combined package would help clarify this.

4. Conclusions

This study examined whether Microsoft Excel-assisted Project-Based Learning could improve the mathematical representation ability of seventh-grade students on the topic of data presentation. Across two cycles of Classroom Action Research, the class mean score rose from 65.16 to 78.39 and the proportion of students reaching the mastery criterion rose from 48.39% to 87.09%, with improvement observed across all six representation indicators assessed. The indicators requiring students to reason across representational registers, comparing and selecting appropriate forms of data presentation, improved the least, consistent with theoretical accounts identifying conversion between representational registers as cognitively more demanding than within-register procedures, and with the broader literature documenting persistent difficulty with graph and data interpretation in statistics education internationally. These findings suggest that integrating Project-Based Learning with spreadsheet technology can meaningfully strengthen junior secondary students' mathematical representation ability, while also indicating that the most conceptually demanding aspects of representation may require sustained, rather than short-cycle, instructional attention to close entirely. For classroom practice, the findings suggest that teachers introducing spreadsheet tools into data-presentation instruction should deliberately design tasks that require students to compare multiple representations of the same dataset and justify their choice, rather than treating chart construction as an end in itself. For school and madrasah policymakers, these findings point to the value of investing in structured TPACK training for teachers, not only providing access to Excel, but building teachers' capacity to integrate it pedagogically into representation-focused tasks, consistent with the broader finding that limited technological-pedagogical integration, rather than lack of access to technology, is the more binding constraint on effective technology-assisted instruction. For future research, quasi-experimental designs that isolate the contributions of Project-Based Learning and Excel-based instruction separately, for example, comparing a PjBL-only class, an Excel-only class, and a combined PjBL-plus-Excel class of similar size over at least four cycles, with a delayed post-test to check retention, longer intervention periods that track the durability of gains on the harder representational indicators, and studies incorporating independent inter-rater scoring would extend and strengthen the evidence base this study contributes to.

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Authors' Contributions

Erna Sari Agusta: conceptualization, methodology, investigation, data curation, writing – original draft. Desy Setyaningsih: formal analysis, validation, writing – review & editing.

Data Availability

The data that support the findings of this study (student test scores, observation notes, and interview transcripts) are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical restrictions, as participants were minors.

Use of Artificial Intelligence

During the preparation of this manuscript, the author(s) used an AI-based language assistant (Claude, Anthropic) to support language editing, restructuring of the manuscript, and formatting of the results and discussion sections. The AI tool was not used to generate, fabricate, or analyse research data or findings. The author(s) reviewed, verified, and edited all AI-assisted content, and take full responsibility for the accuracy and integrity of the content of this publication.

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