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Journal of Research in Educational Sciences

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Enhancing Students' Fraction Comparison Skills Through Teacher Development

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Abstract: This study investigates the effects of a professional development (PD) program for mathematics teachers on improving the teaching of fractions, with a particular focus on fraction comparison. The study aims to examine how continuous, structured PD can enhance both teachers' instructional practices and students' learning outcomes.

Four middle school teachers and 130 students participated in a year-long intervention, consisting of seven cycles of planning, teaching, and reflection. Student performance was assessed using tasks measuring comparison and ordering of fractions, and results were compared with a control group. Teachers' experiences and reflections were collected through observations and self-reports.

Students in the intervention group showed significant improvement in comparing and ordering fractions compared to the control group. The most notable gains were observed in tasks involving comparison with reference points and proximity to reference points. Teachers reported increased awareness of the structure of teaching materials, adoption of more methodical teaching strategies, and enhanced reflection on instructional design.

The study shows that long-term, focused PD with structured methods leads to measurable improvements in teaching and enhances students' conceptual understanding of fractions, highlighting the importance of sustained, targeted teacher support.

The study is limited by the small number of participating teachers, which may affect generalizability. Further research could investigate larger samples and different grade levels.

The results suggest that school leaders should consider long-term, iterative PD programs with structured cycles to support teacher development and student achievement.

Keywords: Teachers, Students, Fraction comparison, Professional development, Middle school

JEL Classification: I21; I28; M53; C83; C93

Introduction

Professional development (PD) programs enable teachers to enhance their skills and knowledge, positively influencing student achievement. A foundational argument for investing in teachers' professional development was established when Carpenter et al. (1989) demonstrated that teachers' expertise and continuous growth have a direct impact on student learning. Since then, numerous studies have reinforced this connection, highlighting how PD shapes effective teaching practices and student outcomes (Darling-Hammond 2017; Pinzón et al. 2024). Previous research highlights a notable discrepancy between teachers' confidence and actual mathematical knowledge, particularly in fractions, underscoring the need for targeted professional development (Li and Kulm 2008; Youkap and Nguala 2025).

Fractions are a critical yet challenging domain of mathematics. They are difficult for students due to their varied representations and interpretations, but mastery is essential for later mathematical success and proportional reasoning (Kilpatrick et al. 2001; Obersteiner et al. 2013). Research shows that students benefit from instruction that highlights conceptual strategies, such as same numerator, same denominator, and benchmark reasoning (Björkhammer et al. 2024; Siegler and Braithwaite 2017). However, many teachers struggle to provide systematic support for students' conceptual learning of fractions, partly due to limited instructional programs and evidence-based guidelines.

This study addresses these challenges by examining the impact of a targeted PD program on the teaching and learning of fraction comparison. Specifically, we ask: (1) To what extent does the PD program affect students' proficiency in comparing and ordering fractions? (2) How do teachers' post-program reflections influence their instructional practice and students' learning experiences?

1. Literature Review

1.1 Fraction Comparison and Instruction

Supporting students' learning of fractions, particularly in comparing and ordering them, requires careful consideration of instructional strategies. Studies in the field categorize fraction comparison strategies into feature-based and rule-based approaches (Obersteiner et al. 2013; Reinhold et al. 2018). Feature-based strategies focus on the attributes of fractions, including transitive reasoning, benchmark reasoning, residual thinking, and piece size reasoning. For example, transitive reasoning relies on using reference points to compare fractions, while benchmark reasoning involves relating fractions to familiar reference points such as 0, 1/2, and 1. Residual thinking emphasizes how much is needed to complete a whole from a given fraction, which is particularly useful for fractions near one (Clarke and Roche 2009). Piece size reasoning highlights that fractions with smaller denominators represent larger parts of the whole (Ni and Zhou 2005). Evidence indicates that students who use feature-based strategies demonstrate stronger conceptual understanding and higher performance (Clarke and Roche 2009; Obersteiner et al. 2013). However, more recent research shows that even students with a solid grasp of fraction magnitude may hold persistent misconceptions when applying procedural rules, and that confidence in their reasoning does not always align with conceptual understanding (Xu et al. 2024).

Rule-based strategies, such as finding a common denominator, are efficient but require a solid understanding of rational number magnitudes (Jordan et al. 2024; Reinhold et al. 2018). Combining feature-based and rule-based strategies has been found to offer the most robust support for students' conceptual and procedural development (Obersteiner et al. 2013). Additionally, visual tools like the number line provide an effective framework for understanding fractional magnitude (Fuchs et al. 2017; Hamdan and Gunderson 2017; Rodrigues et al. 2024). Findings from prior work demonstrate that students who learn fraction comparison using number lines are better able to transfer their understanding to new tasks and perform more successfully in fraction computation and later algebra (Fuchs et al. 2021; Jayanthi et al. 2021). Integrating Van de Walle's (2021) four-step strategies—same denominator, same numerator, benchmark comparison, and closeness to a benchmark—within number line instruction further supports students' fraction reasoning.

Collectively, these studies underscore the importance of integrating multiple strategies and visual representations to foster robust conceptual understanding in students' fraction learning.

1.2. Professional Development Programs for Mathematics Teachers

Effective professional development (PD) programs aim to transform teachers' knowledge, beliefs, and instructional practices, ultimately enhancing student learning (Desimone 2009; Timperley et al. 2007). Research emphasizes several key features of successful PD: a strong content focus, active learning, collaboration, coaching and expert support, feedback, and sustained duration (Artman-Meeker et al. 2022; Darling-Hammond 2017). Short-term or fragmented PD often fails to produce lasting changes, whereas long-term, cyclical programs provide opportunities for teachers to refine their practice based on iterative feedback and reflection (Cobb et al. 2003; McKie 2024; Timperley et al. 2007).

Collective participation, such as school-based teacher teams, can enhance the effectiveness of PD by fostering professional dialogue and collaboration (Porter et al. 2005; Desimone et al. 2002). However, evidence shows that collegial learning alone is insufficient for improving student outcomes, highlighting the need for systematic support and leadership engagement (Mouwitz 2001; Sinnayah et al. 2024; Timperley et al. 2007). Situated learning theory underscores the importance of aligning PD with the classroom context, including student characteristics and curriculum demands (Korthagen 2010; Lee and Vongkulluksn 2023). Structured reflection is a critical component, enabling teachers to evaluate their instruction and make informed adjustments (Diseth 2025; Drake and Sherin 2006; Eun 2010).

Collectively, the research underscores that effective PD programs are continuous, context-specific, and content-focused. Such programs can strengthen teachers' instructional practices in teaching fractions, thereby improving students' conceptual understanding and ability to compare and order fractions.

2. Method

2.1. Participants

Four middle school teachers, with teaching experience ranging from 1 to over 20 years, participated in a year-long professional development (PD) project. Long-term engagement in PD has been shown to positively impact teachers' knowledge, beliefs, and instructional practices (Polly et al. 2014). A total of 130 students, aged 10–11 years, were included in the study. Students were divided into an intervention group (84 students) and a control group (46 students). The sample consisted of 91 girls and 39 boys, reflecting the gender distribution within the participating classes.

2.2. Professional Development Program

The PD program was designed following an action research methodology, allowing for continuous planning, action, and reflection in cyclic processes (Carlgren 2012; Cobb et al. 2003; Timperley et al. 2007). Action research has been described as "directly relevant to classroom instruction and learning and provides a means for teachers to enhance their teaching and improve student learning" (Stringer 2007).

Specific content on fractions was emphasized, as participating teachers had identified that students struggled particularly with fraction comparison. The PD program consisted of seven cycles: Cycle 1 – Project Design and Initial Discussions: Various strategies for comparing fractions were discussed, including (a) same numerator, (b) same denominator, (c) close to ½, and (d) close to 1. A test was constructed to measure students' prior knowledge, and the results were analyzed to guide lesson progression. Cycle 2 – First Lesson: Focused on comparing fractions with the same numerator. Van de Walle's principles were implemented, with emphasis on using a number line to visualize fraction magnitudes. Students learned to compare fractions such as 3/8 and 5/8. Cycle 3 – Second Lesson: Focused on comparing fractions with the same denominator. Students developed an understanding of how numerators determine size when denominators are identical. Cycle 4 – Third Lesson: Focused on fractions close to the reference point ½, encouraging students to estimate and reason relative to ½ as a benchmark. Cycles 5–6 – Fourth and Fifth Lessons: Focused on fractions close to 1. After initial observations indicated difficulty, the cycle was repeated with additional practical exercises. Cycle 7 – Sixth Lesson: Focused on mixed categories of tasks. Following this cycle, a post-test was administered, and interviews with teachers were conducted and analyzed.

Each lesson lasted approximately 50 minutes and followed a structured sequence. Lessons began with a brief review of the previous strategy to reinforce learning. Explicit instruction, modeling, guided practice, and independent practice were applied consistently (Gersten et al. 2009). Number lines were used in all lessons to support visualization of fractions (Barbieri et al. 2020). Exit tickets were used to assess understanding, and the 80% criterion was applied: if at least 80% of students answered correctly, instruction moved forward; otherwise, content was revisited (Archer and Hughes 2011). A shared PowerPoint presentation and carefully selected tasks were used to ensure consistency across lessons.

The control group received treatment-as-usual instruction using standard fifth-grade materials (Mattedirekt, Falck and Carlsson 2021). Instruction focused on conceptual understanding of fractions and matched the intervention group in lesson number and duration, but no additional guidance was provided.

2.3. Data Collection

Data were collected using two complementary types of assessments, designed to measure students' fraction knowledge and to capture teachers' professional reflections.

Students' abilities in comparing fractions were evaluated through a pre-test and post-test, each consisting of 16 tasks. The tasks were divided into four categories: same denominator, same numerator, close to ½, and close to 1. The tests were piloted with a small group of students prior to the main study to ensure clarity and reliability. Administration was conducted digitally via Google Forms, a format familiar to the students from previous experiences.

Teachers' reflections were gathered through individual interviews conducted after completion of the PD program. An interview guide was used to maintain consistency and focus during the discussions, which lasted approximately 60 minutes each. The interviews explored teachers' experiences and reflections on their learning, their application of the strategies in the classroom, challenges encountered, and perceived impacts on students' engagement and performance.

2.4. Data Analysis

To investigate the effects of the professional development program, quantitative and qualitative data were analyzed. For the quantitative analyses, a two-way analysis of variance (ANOVA) was conducted, with group (intervention vs. control) as a between-subjects factor and time (pre-test vs. post-test) as a within-subjects factor. Dependent variables included overall performance on fraction tasks as well as performance on each strategy category: same denominator, same numerator, benchmark comparison, and closeness to a benchmark.

Qualitative data from teacher interviews were analyzed using thematic analysis (Braun and Clarke 2012). The analysis followed a six-phase process: (1) familiarization with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. Initial codes included "focused teaching strategies," "structured methods," "choice of examples," "importance of repetition," and "professional reflections on teaching materials." Four final themes were identified: (I) Focused Content Enhances Fraction Teaching, (II) Structured Methods Enhance Fraction Teaching, (III) Accurate Choice of Examples Enhances Fraction Teaching, and (IV) Repetition Enhances Fraction Teaching. Illustrative quotes were included to demonstrate how teachers' practices evolved and influenced student learning.

2.5. Ethical Considerations

Informed consent was obtained from all participants and their guardians prior to the study, in accordance with the Swedish Research Council guidelines (2024). Data were anonymized and stored securely, and all materials were used exclusively for research purposes. The study adhered to ethical principles outlined in the Declaration of Helsinki. According to the Swedish Act concerning the Ethical Review of Research Involving Humans (SFS 2003:460), formal ethical approval was not required as no sensitive personal data were processed, and no physical interventions were conducted. All potential risks to participants were carefully considered.

3. Research Results

The results are presented in two sections. The first section reports the quantitative findings from the student tests, while the second section presents the qualitative findings from teacher interviews.

3.1. Quantitative Findings on Students' Fraction Proficiency

Descriptive statistics for the groups' performance on the four strategy categories—same denominator, same numerator, benchmark comparison, and closeness to a benchmark—as well as total scores, at pre- and post-test, are presented in Table 1. Improvements from pre- to post-test and Cohen's d effect sizes are also reported.

Table 1. Number of Participants, Means, Standard Deviations, and Improvements for the Math Test by Group and Timepoint

			Before			After		Improvement	
Test	Group	n	M	SD	n	M	SD	M	Cohens´d
Total	Control	46	7.93	3.98	46	9.63	3.27	1.70	0.47
Total	Intervention	84	8.42	3.09	84	12.2	2.31	3.78	1.39
Same size denominators	Control	46	1.87	1.28	46	1.87	1.15	0	0
Same size denominators	Intervention	84	1.88	1.02	84	2.50	0.83	0.62	0.67
Same size numerator	Control	46	1.57	1.31	46	1.96	1.21	0.39	0.33
Same size numerator	Intervention	84	1.88	1.16	84	2.68	0.64	0.80	0.78
Benchmark comparison	Control	46	1.70	0.94	46	2.35	0.67	0.65	0.31

			Before			After		Improvement	
Benchmark comparison	Intervention	84	1.51	0.77	84	2.58	0.59	1.07	1.56
Closeness to a benchmark	Control	46	1.93	1.14	46	2.22	0.99	0.29	0.25
Closeness to a benchmark	Intervention	84	1.94	0.84	84	2.92	0.95	0.98	1.09

To examine differences between groups over time, a two-way analysis of variance (ANOVA) was conducted with group (intervention vs. control) as a between-subjects factor and time (pre-test vs. post-test) as a within-subjects factor. Dependent variables included total performance as well as performance on each strategy category.

Total scores showed a significant interaction between group and time, $F(1, 128) = 21.9$, $p < .001$, $\eta^2p = 0.146$. A main effect of time, $F(1, 128) = 186.2$, $p < .001$, $\eta^2p = 0.593$, indicated substantial improvement across both groups, and a main effect of group, $F(1, 128) = 9.84$, $p = .002$, $\eta^2p = 0.071$, suggested overall differences between the intervention and control groups.

For fractions with the same denominator, the interaction was not significant, $F(1, 129) = 0.027$, $p = .869$. However, students' performance improved significantly over time, $F(1, 129) = 13.54$, $p < .001$, $\eta^2p = 0.10$, while no difference between groups was observed.

Fractions with the same numerator also showed no significant interaction, $F(1, 129) = 2.80$, $p = .097$. Nevertheless, significant main effects were found for time, $F(1, 129) = 36.04$, $p < .001$, $\eta^2p = 0.22$, and group, $F(1, 128) = 9.84$, $p = .002$, $\eta^2p = 0.071$.

Benchmark comparison revealed no interaction effect, $F(1, 129) = 1.32$, $p = .253$, but a robust improvement over time, $F(1, 129) = 117.34$, $p < .001$, $\eta^2p = 0.48$, with no significant group difference.

Closeness to a benchmark demonstrated similar patterns: the interaction effect was non-significant, $F(1, 129) = 0.80$, $p = .373$, yet a main effect of time indicated significant performance gains, $F(1, 129) = 61.52$, $p < .001$, $\eta^2p = 0.32$. Group differences remained non-significant.

Overall, the intervention group exhibited marked improvements in total test scores (Cohen's $d = 1.39$) and strategy-specific gains, particularly in benchmark comparison ($d = 1.56$) and closeness to a benchmark ($d = 1.09$), suggesting that the professional development program effectively supported students' conceptual understanding of fractions.

3.2. Qualitative Trends in Teachers' Reflection

This section presents findings from teacher interviews, focusing on their experiences and reflections after participating in the professional development (PD) program. The analysis explores how the program influenced teachers' learning, instructional practices, and students' experiences.

Teachers reported a shift toward more focused and structured teaching of fractions. They emphasized the value of addressing one concept at a time, beginning with simpler tasks, such as comparing fractions with the same numerator or denominator, and gradually introducing more complex concepts, including benchmark comparisons. One teacher explained, "During this project, we focused on one thing at a time… You notice that the next step is much harder because you have to think in two steps, understanding both how much is missing and how big it is." This step-by-step approach enabled students to develop a deeper understanding of fractions and to articulate their reasoning more explicitly over time.

In addition, teachers highlighted that structured instructional methods enhanced students' strategy use and metacognitive awareness. Before the PD program, lessons were often fragmented, but the program promoted coherence and progression. As one teacher reflected, "Before the project, it felt like a lot in the math lessons came a bit all over the place. During the project, the students became very strategic in their approach to comparing fractions, and we noticed we had great success with focusing on one strategy at a time and then training on it." Students increasingly explained why they selected particular strategies, demonstrating growth in mathematical reasoning.

Teachers also recognized the importance of accurate task and example selection. Improved assessment methods, such as exit tickets, allowed teachers to monitor student reasoning and adjust instruction accordingly. One teacher noted, "Through exit tickets, students not only answered but also explained their reasoning, helping teachers identify misconceptions and adjust instruction." These practices enhanced student engagement and supported more effective teaching.

Repetition emerged as a key strategy in reinforcing learning. Teachers reported that repeated practice helped students consolidate understanding, even when initial resistance occurred. One teacher observed, “At first, many students struggled to explain their thinking, especially with multi-step comparisons, but repeated practice helped their reasoning become clearer and more precise.” Over time, students demonstrated growing confidence in articulating fraction comparisons and recognizing patterns.

Overall, the PD program significantly enhanced teachers’ ability to teach fractions. Structured lessons with clear examples and repetition improved student outcomes, motivation, and reasoning. The step-by-step approach facilitated students’ strategic thinking, while improvements in assessment methods and task design further supported learning. These findings illustrate how the PD program promoted both teacher professional growth and students’ conceptual understanding of fractions.

4. Discussions

The present study investigated the impact of a targeted professional development (PD) program on teachers’ instructional practices and students’ understanding of fractions. The findings indicate that the PD program contributed to improvements in both student learning and teachers’ professional growth. Pinzón et al. (2024) similarly emphasize that well-designed PD initiatives can lead to measurable gains in student achievement, reinforcing the relevance of such interventions. Taken together, these results underscore the value of structured, content-focused, and sustained professional development for enhancing mathematics instruction. Students in the intervention group demonstrated notable gains in fraction comparison, particularly for tasks involving benchmark reasoning. Targeted strategies have been shown to strengthen students’ conceptual understanding of fractions. Björkhammer et al. (2024) emphasize that instruction targeting conceptual understanding of fraction magnitude—such as through benchmark reasoning—can significantly improve students’ fraction comparison performance in whole-class settings. Furthermore, prior research highlights the value of feature-based strategies, visual support, and explicit instruction for promoting fraction knowledge (Clarke and Roche 2009; Obersteiner et al. 2013; Siegler et al. 2010).

Students’ performance improved most substantially in benchmark comparison tasks and in the application of strategies that required deliberate reasoning, such as evaluating closeness to a benchmark. These findings suggest that the PD program effectively addressed persistent challenges in fraction learning. This includes misconceptions and difficulties with conceptual strategies. Consistent with previous studies, the combination of explicit instruction, visual representations such as number lines, and repetitive practice appeared critical for consolidating students’ understanding and facilitating transfer to new tasks (Barbieri et al. 2020; Fuchs et al. 2017; Rodrigues et al. 2024; Rohrer and Taylor 2006; Van de Walle 2021). The large effect sizes observed for benchmark comparison (Cohen’s d = 1.56) and closeness to a benchmark (Cohen’s d = 1.09) further underscore the practical significance of the intervention, complementing the quantitative results reported in the results section.

Teachers’ reflections indicated professional growth in multiple areas, including instructional structuring, task selection, and use of student reasoning to guide teaching. The step-by-step approach, focusing on one strategy at a time and gradually increasing task complexity, fostered more coherent and deliberate instruction. These findings are consistent with the literature on effective PD programs, which emphasize content focus, iterative cycles, and contextualized learning within teachers’ own classrooms (Desimone 2009; Korthagen 2010; Timperley et al. 2007). Teachers’ increased awareness of task design and assessment, including the use of exit tickets, contributed to enhanced monitoring of student understanding and informed instructional adjustments. This supports the need for professional development that bridges the gap between teachers’ confidence and their actual mathematical understanding, as highlighted by Youkap and Nguala (2025). Furthermore, this aligns with research highlighting the importance of reflection and data-informed practice (Diseth 2025; Drake and Sherin 2006; Eun 2010).

An additional contribution of this study is the emphasis on repeated practice and scaffolding in supporting student learning. Teachers observed that iterative exposure to fraction comparison tasks allowed students to consolidate strategies and articulate reasoning with increasing precision. This observation supports prior research on the importance of repetition for mastery and retention, particularly in the context of challenging content such as fractions (Rohrer and Taylor 2006). In addition, structured support and feedback provided by the PD program facilitated teachers’ implementation of effective instructional strategies. This demonstrates the critical role of ongoing, cyclical support in professional development (Artman-Meeker et al. 2022; Carlgren 2012).

Several factors appear to have contributed to the observed outcomes. McKie (2024) highlights that sustained and collaborative PD structures are essential for long-term instructional improvement, which aligns with the design of the present intervention. The PD program’s long-term and context-specific design, the use of collective participation with support from an external researcher, and structured opportunities for reflection enabled teachers to refine their practices and integrate new strategies effectively. These elements align with research identifying essential features of successful PD programs, including collaborative learning, continuous engagement, and alignment with classroom practice (Darling-Hammond 2017; Desimone et al. 2002; Timperley et al. 2007). However, Sinnayah et al. (2024) argue that collegial learning must be complemented by structured support and leadership engagement to effectively impact student outcomes. Importantly, the integration of PD with immediate classroom application allowed teachers to connect their learning directly to student outcomes, enhancing both relevance and effectiveness.

Despite these positive results, some limitations should be acknowledged. Improvements were less pronounced for fraction comparison strategies such as same denominator, likely due to their intuitive nature. Additionally, the quasi-experimental design limits causal inferences, and factors such as classroom context and fidelity of implementation could have influenced outcomes (Shadish et al. 2002). The study also did not include direct observations of classrooms or interviews with students, restricting insight into students' reasoning processes and the enactment of instructional changes. Future research should incorporate multiple data sources, including student perspectives and classroom artifacts, to provide a more comprehensive understanding of how PD impacts both teacher practice and student learning.

In conclusion, the PD program effectively enhanced teachers' ability to deliver structured, research-informed instruction and improved students' conceptual understanding of fractions. The study reinforces the importance of linking professional development to student learning outcomes. It provides evidence that sustained, content-focused, and contextually grounded PD can promote both teacher growth and measurable improvements in student achievement. These findings offer practical guidance for designing future PD initiatives and contribute to the growing body of evidence supporting the integration of research-based instructional methods in mathematics education.

Conclusions and Further Research

The professional development program significantly enhanced teachers' ability to teach fractions, leading to better student outcomes. Focusing on the relationship between teachers' development and student achievement is essential. By incorporating key activities aligned with effective PD programs and focusing on structured strategies, such as benchmark comparison and repetition, the intervention effectively addressed student learning in comparing fractions. By supporting teachers in designing structured, research-informed lessons, the PD program enabled students to engage more deeply with mathematical content and articulate their reasoning more clearly. These findings contribute to the growing body of evidence supporting the integration of research-based instructional methods in mathematics education, offering practical insights for future program development and implementation.

Future research could examine the long-term sustainability of such professional development programs and their potential effects on other areas of mathematics beyond fractions. Incorporating classroom observations, student interviews, and instructional artifacts would provide a deeper understanding of how instructional changes are enacted and how students reason during learning activities. Additionally, investigating differentiated approaches to PD—considering teacher experience, classroom context, and student needs—could enhance the scalability and effectiveness of such interventions.

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Credit Authorship Contribution Statement:

Cecilia Sveider: Conceptualization, Project administration, Investigation (teacher interactions and interviews, student test data collection), Formal analysis (quantitative and qualitative data), Writing – original draft (quantitative results, qualitative results, fraction-related literature review), Writing – review and editing, Supervision.

Joakim Samuelsson: Writing – original draft (discussion, PD-related literature review), Formal analysis (supporting role in quantitative and qualitative analyses), Writing – review and editing.

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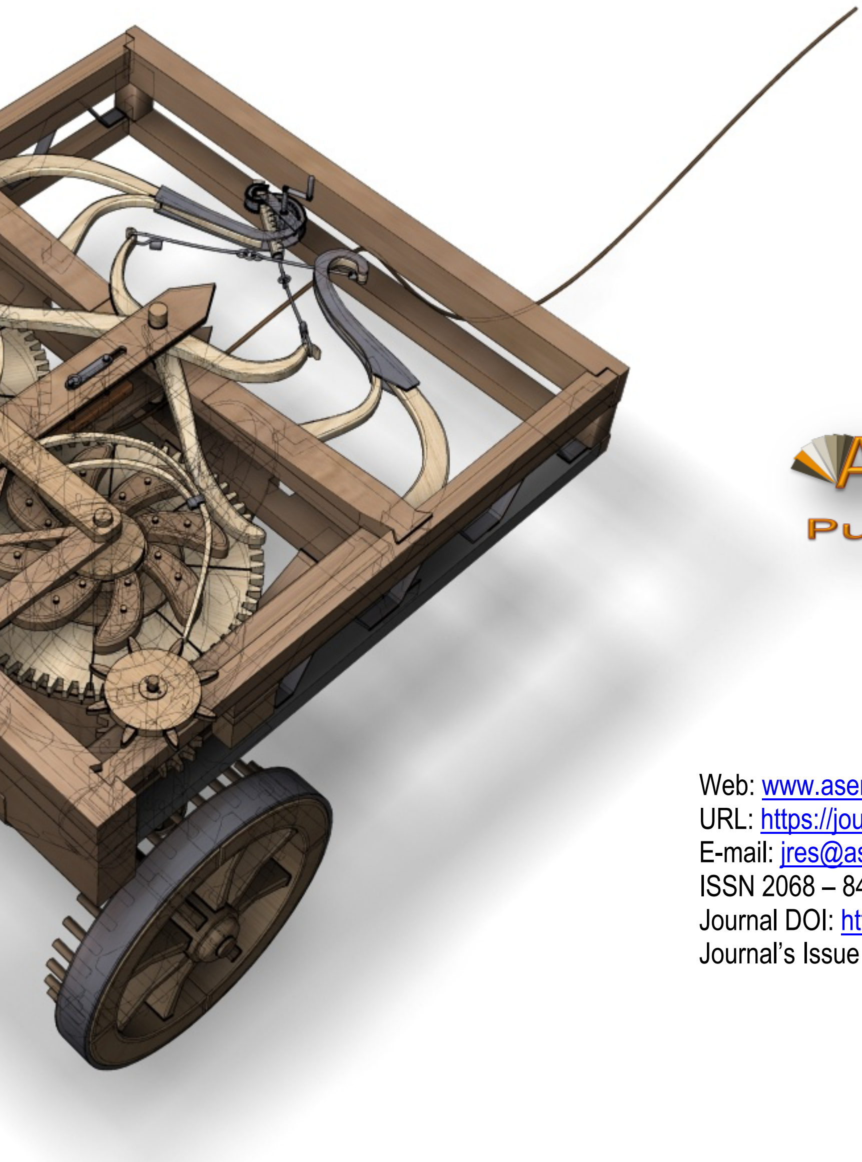

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