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Eureka: A Panacea in Students' Procedural Fluency along Concepts of Forces and Motion

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Abstract This study aims to assess the effectiveness of a teacher-created intervention strategy, known as Project EUREKA, in enhancing students' procedural understanding of forces and motion. The study focuses on promoting mastery of concepts and procedural skills through the utilization of the 3-Tiered Instructional Model, hands-on science through digital lab activities and real-life model to facilitate students' learning process. The mixed-method research design was employed to assess the effectiveness of a researcher-initiated intervention program in the context of forces and motion. The study utilized both quantitative and qualitative data to examine the participants' experiences and the impact of the program. The quantitative analysis, conducted using the One Group Pretest-Posttest Design (OGPPD), demonstrated that students made greater improvements in conceptual understanding compared to procedural fluency. These findings underscore the importance of conceptual understanding in fostering procedural fluency and highlight the reciprocal relationship between these two types of knowledge. Statistical analyses further confirmed the significance of the results, with p-values less than .001 for both procedural fluency and conceptual understanding, indicating a high level of significance. The provisions of Project EUREKA successfully unleashed the thrill and joy of learning, ignited boundless curiosity during experimentation, and demonstrated a transformative power in enhancing students' procedural fluency. Owing to the results, this study provides valuable insights for theory and practice emphasizing the significance of conceptual understanding, supporting the effectiveness of the intervention program, and suggesting the adoption of engaging and transformative educational approaches to enhance students' learning outcomes.

Keywords*: 3-Tiered Instructional Model, Home-based laboratory, Project EUREKA, Procedural Fluency, Real-life Model*

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1. Introduction

Education is often considered a key factor in determining future success, as it provides individuals with promising opportunities and paves the way for a prosperous future [1]. The Department of Education (DepEd) has made it a priority to ensure that no student is left behind. In pursuit of this goal, inclusive learning has become a cornerstone of the K–12 Basic Education Curriculum. This approach ensures that all learners have an equal opportunity to progress at their own pace through a diverse range of learning activities.

In line with this, a joint research center emphasized the importance of DepEd's priorities on the improvement of learners' literacy and numeracy skills based on the World Bank report released in 2021. It revealed that Filipino students ranked poorly in the multilateral lender's assessments of math, science, and reading proficiency. Consequently, teachers face significant challenges in enhancing students' procedural fluency to meet the fast-paced demands of today's educational landscape.

The educational landscape in the Philippines presents significant challenges. As mentioned by the Trends in International Mathematics and Science Study 2019, a mere 13 percent of Filipino students demonstrated a "limited understanding of scientific concepts and limited knowledge of foundational science facts" placing them in the Low benchmark category. Apparently, a staggering 87 percent of students did not even reach this level. These alarming statistics are further exacerbated by the low rankings of Filipino students in the Program for International Student Assessment (PISA) for mathematics and science, scoring 353 points and 357 points, respectively, compared to the OECD average of 489 for both subjects. In light of these pressing issues, DepEd recognizes the urgent need to address the gaps and challenges in delivering quality basic education in the Philippines.

Teaching physics in the high school setting poses a challenge for educators, as highlighted in studies

conducted by Bautista [2] and Ginsburg [3]. The subject is often perceived as difficult due to the integration of conceptual and mathematical analysis and the prevailing belief that math-related subjects are inherently challenging. Physics, being a hybrid course, demands both conceptual understanding and procedural fluency. Ginsburg's [3] research indicates that conceptual understanding in learning goes beyond mere rote memorization.

To foster procedural fluency in students, it is crucial to provide them with opportunities to integrate concepts, processes, and familiar methods that allow them to develop their own informal strategies and procedures [4]. The research of Bautista [2] further emphasizes the influence of students' mathematical and English abilities on their procedural fluency and written-mathematical explanations.

Physics posts the lowest General Weighted Average (GWA) over the last three years in Cabaruan Integrated School. The Grade 9-Peace GWA from SY 2019-2021 performed poorly with the scores of 77.2, 76.6, and 77.6. During the diagnostic test, the concepts in forces and motion were identified as "least mastered" with an MPS of 38.87 in the school year 2021-2022; and this needs immediate action. This, however, demonstrates the learners' lack of conceptual understanding, strategic reasoning, procedural fluency, and problem-solving ability. Furthermore, these provide a plethora of ideas for developing a teaching strategy that will cater the students' motivation to learn while improving their overall performances. Aptly, conceptual understanding and procedural fluency must go hand in hand to ensure students' learning and mastery of concepts and procedures in Physics. Thus, the objective of this research is to enhance students' procedural fluency for forces and motion in Physics through the implementation of Project EUREKA.

1.1. Objectives of the Study

This study aims to determine the effect of Project EUREKA on improving the procedural fluency of the students along concepts of forces and motion in Physics. Specifically, it aimed to: (1) determine the performance of Grade 9-Peace in Physics before and after the implementation of EUREKA; (2) evaluate significant difference on the performance among Grade 9-Peace before and after the implementation of the EUREKA along forces and motion in Physics; (3) evaluate on the effect size of Project EUREKA on the students' procedural fluency along forces and motion in Physics of Grade 9-Peace; and (4) describe the experiences of the students on the provisions of project EUREKA.

1.2. Theoretical Framework of the Study

The conditions and parameters of this study are anchored on three governing theories: Constructivist Theory of Learning, John Dewey Theory, and Vygotsky's Social Learning Theory.

Constructivist Theory of Learning. The mainstream of this idea holds that people's knowledge is built on their own experiences. The more the learners' involvement, the more knowledge they create through activities.

John Dewey Theory concept of "learning by doing." The theory posits the importance of learning through experience and active engagement with the world. Students should be engaged in hands-on, experiential activities that allow them to apply what they learn in real-world contexts.

Vygotsky's Social Learning Theory. The theory holds that learning occurs in the context and cannot be isolated from the social environment. This idea describes how humans learn from one another via encounters and conversation. Through the perspective of this idea, it creates an atmosphere of guided and directed interactions to occur.

2. Methodology

This study employed the Mixed-method research design, namely the Exploratory design, which included quantitative and qualitative data on the efficacy of the researcher-initiated intervention program as well as the participants' experiences. The setting, which includes a quantitative analysis that is a primary consequence of the intervention, is supported by the participants' rich experience. To put it succinctly, the One Group Pretest-Posttest Design (OGPPD) and Narratology were used.

This study is a panacea for increasing the procedural fluency in forces and motion among the 33 students of Grade 9-Peace of Cabaruan Integrated School. The researcher dubbed this intervention as Project EUREKA, which stands for **E**laborating and **U**nderstanding procedural fluency in physics through **R**ealia and **E**xperimentation using Arduinno Science Journal App and PHET Simulation App under the concept of digital lab activities honed by **K**een and collaborative **A**pproach in learning science.

The Intervention Program. Following the **Three-Tiered Instructional Model**: In Tier 1, the teacher divided the participants into small learning groups and does the presentation of the lecture and discussion of a given specific topic. The teacher made use of different strategies during the discussion like doing daily routines, warm up activities, and exercises to encourage participation. This is followed by a formative test. The result of the formative test in tier 1 was used as one of the bases for the selection of tutors to those learners with low scores and will undergo Tier 2. The teacher assigned one leader per group accordingly. The teacher tutored the study leaders through peer-assisted learning ahead of time so they can master the concepts. Study leaders were guided and tutored in the concept's ideation. Tutors were given guides and instructions, and set of exercises for the tutoring activity. Finally, Tier 3 was conducted through pair and group tutoring, in which the teacher assigns trained study leaders to functional groups such as diads, triads, and others by a performing student to a least performing student based on their results in the formative test in Tier 2. The teacher guided them through techniques for transferring the concept to their classmates in a way that is as comprehensible as the teacher's method of delivering it to them. In this section, all participants in each learning group will repeat the process of creating a realia and experimentation through the Arduinno Science

Journal App and PHET Simulation App in order to improve their comprehension and collaboration.

Since the subject is science, real objects are visualized through simulations using **realia**. The simulation was modeled by the teacher, who has a thorough understanding of the concept. In addition, the creation of real-life model or realia of the concepts being taught allows children to make connections to their own lives as they try to make sense of new concepts and ideas. This sparked the participants' creativity and comprehension. The model allowed the participants to engage in a variety of activities related to key concepts and requires them to scientifically explain such concepts using mathematical processes. Respondents made an **EGG CAR MODEL** which explain the relationship between mass and velocity.

Participants were assigned **digital lab activities** to complete using the Arduino Science Journal App and PHET Simulation App. Each activity has its own set of procedures to follow and the results can be validated using an online science app with simulated procedures and outcomes. Participants were given specific links for each activity to help them verify their findings and enrich their learning. Each link displays simulation activities. There are 3 digital lab activities that are synchronized with the three sessions using the Arduino Science Journal APP and PHET Simulation App, an interactive and user-friendly application that covers theoretical and laboratory sessions across various branches of science and grade levels

After performing the activity and problem set, the participants were allowed to discuss the topics in pairs or groups in order to broaden and strengthen their knowledge. There was a **wrap-up session** every Friday of the week where they shared and discussed their findings with their classmates and teacher. Each activity was completed for one week, followed by another in the following week. All activities were carried out with the help and supervision of the parents and teacher.

The means of collecting the data for the research include an adopted test questions from their Activity Learning Sheet of DepEd Region 2 to measure the procedural fluency of the respondents. The adopted test question is a 6-item problem solving test measuring the procedural fluency of the respondents. The 6-item problem solving test were measured through an adopted rubric. An analytical rubric is re-formulated based on Pugale's model rubric (2004) and anchored on Mayer's model for problem solving. It provides sufficient details in differentiating the levels of performance of the students on procedural fluency and written mathematical explanations.

3. Results and Discussion

3.1. Effectiveness of Project EUREKA on Students' Fluency along concept of forces and motion.

Presented in Table 1 are the mean scores of the students in their procedural fluency and conceptual understanding in forces and motion along with the Standard Deviation (SD) of the scores. As to procedural fluency, the mean difference, 17.939, is derived from the pretest and posttest results: 10.152 and 28.091, respectively. On the other hand, the mean difference of 15.606 along the conceptual understanding of the respondents is derived from the pretest and posttest results: 6.485 and 22.091, respectively. Apparently, the SDs for procedural fluency and conceptual understanding suggest that the concordances of the students along Conceptual Understanding are more consistent than their procedural fluency: .998 and 1.619, respectively.

With the empirical evidences, Baroody, Feil, and Johnson's [5] model explicates the students' need on knowledge in both concepts and procedures and that they have an influence on each other. However, students who learned through a conceptual approach had more flexible knowledge and were able to transfer knowledge to new situations. Henceforth, according to Clark [6], concepts have the 'capacity' for organization and association, they are the most powerful and useful cognitive tools available to people. In essence, a concept is an idea that is well understood enough that it can be linked to other ideas and become part of a web of understanding. Such links and webs frequently result in the formation of conceptual knowledge. Furthermore, the study of Pesek and Kirshner [7] shows that students who are taught for a conceptual understanding followed by a procedural understanding outperform students who are instructed for procedural then conceptual knowledge. Moreover, Rittle-Johnson and Alibali [8] demonstrated that conceptual and procedural knowledge are used iteratively and that both can develop from the other.

Table 1. Mean scores of the students in their procedural fluency and conceptual understanding in forces and motion along with the Standard Deviation (SD) of the scores

Particulars		Pretest	Posttest	Mean Difference	SD
Procedural Fluency	Mean Score	10.152	28.091	17.939	1.619
	SD	1.986	1.041		
Conceptual Understanding	Mean Score	6.485	22.091	15.606	.998
	SD	1.064	1.042		

Table 2. t-Test on the Pretest and Posttest of Students along their Procedural Fluency and Conceptual Understanding in Forces and Motion

Particulars	t-value	p-value	r	Interpretation
Procedural Fluency	-63.652	.000*	.582	Medium
Conceptual Understanding	-15.251	.000*	.551	Medium

*significant at .05 level; r represents Cohen's D

Presented in Table 2 are the t-test and correlation scores of the students in their procedural fluency and conceptual understanding on forces and motion. It denotes that the p-values of both procedural fluency and conceptual understanding of the students are less than .001, which further suggests very highly significant results. Likewise, the effectual correlation of the scores reveals that the project EUREKA made a medial effect on the dependent variables: procedural fluency and conceptual understanding in forces and motion. The foregoing results lead to the rejection of the null hypothesis which states that there is no significant effect of intervention program

(EUREKA) on the procedural fluency and conceptual understanding in forces and motion. Henceforth, EUREKA is effective in raising the procedural fluency and conceptual understanding.

This result authenticates the findings of Rittle Johnson and Schneider [9] views that the relationship of procedural and conceptual understanding is bilateral which one increases and generates increases in other. Research findings claim that there is a correlation between procedural and conceptual knowledge across a range of domains and ages [10,11,12,13,14,15,16]

3.2. Experiences of the Students on the Provisions of Project EUREKA

Unleashing the thrill and joy in learning. Creating an exhilarating and gratifying educational experience ignites a deep sense of enjoyment, curiosity, and enthusiasm among learners. Through engaging activities like the digital lab experiment, such as the captivating egg cart experiment, learners experience immense pleasure and a heightened sense of wonder, even amidst challenging times like the CoViD-19 pandemic.

The following transcripts qualify the claim of the study:

"…I enjoyed doing the given activities in our digital lab experiment, particularly the egg cart experiment…" Z4

"…I**t** brought immense enjoyment, especially during the challenging times of the CoViD-19 pandemic, as it sparked **my** curiosity..." Z3

"…The best thing that I felt when the boiled egg got cracked and its relation to the motion of the car…" Z2

"…as to my teammates, we always learned new things specially the value of learning together …" Z1

"…when we conducted digital lab experiment, I learned a lot: filled with fun and interesting and the release in the PHET simulation…" Z5

The above transcripts support the idea that incorporating digital tools and platforms, such as the digital lab experiment, can enhance learner engagement, enjoyment, and curiosity, even in challenging times [17,18]. Additionally, studies on the role of curiosity in teaching and learning emphasize its significance in creating captivating and enjoyable educational experiences.

Igniting boundless curiosity in experimenting. Sparking limitless inquisitiveness during the experimentation phase is always wanting in science. It involves encountering and overcoming difficulties or obstacles while maintaining a deep sense of curiosity, which ultimately leads to meaningful discoveries and successful outcomes.

"…I experienced difficulty in manipulating the application and my curiosity helps me…" Z4

"…I found obstacle in doing experiment because there were times that I do not know the next thing to do…" Z6

"…I encountered adversity while preparing the activities because of too much excitement…" Z5

"…I was curious at first what may happen to the egg then because of my focus on egg I did not realize the effect that may happen to my phone…" Z7

"…The interesting part is that I and my group mates made a bet on how far does the release of the arrow in the activity and we repeat it because our approximation is wrong…" Z9

"…our suggestions in our group made our activity meaningful specially the car we brought is too much small…" Z1

The above transcripts support the claim of Lai [19] on investigating the roles of curiosity, interest, and intrinsic motivation in educational game design. This can be used to discuss how maintaining a sense of curiosity during the experimentation phase can enhance intrinsic motivation and interest in the learning process.

Transformative power of Project EUREKA in enhancing procedural fluency. The provisions of Project EUREKA bring significant positive changes and improvements on procedural fluency. The project's engaging activities such as solving problems, working with formulas, and participating in group activities facilitate a deeper understanding of concepts and enhance procedural knowledge. The transformative power of Project EUREKA lies in its capacity to make solving and procedural learning more enjoyable, accessible, and effective for learners.

The following transcripts qualify the claim of the study:

"…I experienced difficulty in solving but the activities helped me understand the concepts…" Z2

"…Sometimes I cannot understand the concepts in science specially physics because of solving. I understand the concepts as I enjoyed and internalized the activities..." Z1

"…I really do not love solving but this activity gives me courage to try because of the engaging activities…" Z10

"…At first while just seeing the formula, it is like I do not know how to use it but it became easy as I integrate in our activities…" Z8

"…working with our leader helped me more in my procedural knowledge specially solving is not easy…" Z5

"…because of the digital lab activities, egg cart model, and group activities, learning becomes easier specially that it is solving which requires critical comprehension…" Z6

The above transcripts support the claim that engaging science activities can impact students' interest, participation, and learning outcomes [17,19]. It can be used to support the claim that the engaging activities in Project EUREKA contribute to students' procedural fluency by making solving and procedural learning more enjoyable and effective.

4. Conclusion

The following conclusions were drawn based on the interpreted data.

1. The students showed a greater improvement in their conceptual understanding of forces and motion

compared to their procedural fluency. This highlights the importance of conceptual understanding in fostering procedural fluency and the reciprocal relationship between these two types of knowledge;

2. The statistical analysis indicates that both procedural fluency and conceptual understanding scores of the students in forces and motion show highly significant results. The p-values for both variables are less than .001, suggest a very high level of significance.
3. The provisions of Project EUREKA indicate that the program successfully unleashed the thrill and joy in learning, ignites boundless curiosity in experimenting, and has a transformative power in enhancing procedural fluency.

5. Implications to Theory and Practice

These implications highlight the importance of conceptual understanding and its role in fostering procedural fluency. The findings provide empirical evidence of the effectiveness of programs like Project EUREKA. This emphasizes the need for engaging and transformative educational approaches. This information guides educators in developing effective instructional strategies and interventions to enhance students' conceptual understanding, procedural fluency, and overall learning outcomes.

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