Development and Evaluation of Frankards: A Manipulative for Teaching Probability

Frankie A. Fran, Ateneo de Manila University and Romblon State University, Philippines
Catherine P. Vistro-Yu, Ateneo de Manila University, Philippines

The Southeast Asian Conference on Education 2023
Official Conference Proceedings

Abstract
This study focused on developing and evaluating an instructional material based on the needs of mathematics teachers and on the least mastered learning competencies in Grade 10 Mathematics. Baseline data gathered revealed that teachers faced difficulties in contextualizing and discussing the concepts of statistics and probability. They specifically cited the lack of instructional materials for the learning competencies under this content area. This served as the basis for the development of *Frankards*, a manipulative designed to aid in teaching the concepts of probability. This study utilized a development research method and adopted the ADDIE Model in creating the manipulative. Subsequently, Frankards was evaluated by teachers and instructional material developers using the standardized Evaluation Rating Sheet for Manipulatives prescribed by the Philippines' Department of Education. Frankards passed all the criteria set for the three areas of evaluation, namely: Contents (Factor A), Other Findings (Factor B), and Additional Requirement for Manipulative (Factor C). Revisions related to the visual aspects of the manipulative were suggested. The evaluators have recommended that the developed manipulative be submitted for copyright. It was further suggested that the effectiveness of the manipulative be subjected to an experimental study. It was also proposed that a teacher training on its use be conducted to further validate its benefits to both teachers and learners.

Keywords: Frankards, Instructional Material, Mathematics Education

Introduction

In teaching and learning, how educators deliver and teach the content is crucial, especially in mathematics. Hence, teachers handling this subject should therefore be proficient in teaching the subject and equipped with the essential skills and strategies. Moreover, it is vital that their goals be based on the current trends in education. Knowing the Department of Education's current curriculum framework enables the teacher to develop and adapt lessons that are suited to the needs of the learners (Braza and Supapo, 2014). In the Philippine setting, mathematics is viewed and perceived as the hardest subject not only by students but also by teachers. In the study conducted by Gafoor and Kurukkan (2015), they have found that 75% of the respondents believed that Mathematics is a difficult subject. With that, teachers tried to innovate and use other approaches to make mathematics a more meaningful and engaging subject, such as visual materials and manipulatives. Leinhardt (1991) emphasized that the utilization of various representations is an integral part of teachers' knowledge of mathematics, and they play a vital role in explaining mathematical concepts. In this connection, researchers and mathematics educators through the years develop and create instructional materials and other aids to address issues in relation to low performance in mathematics. In the study conducted by Moyer (2001), he concluded that teachers play a significant role in creating mathematical environments that help students in acquiring knowledge and improving their learning through visual representations. Vinson (2001) also stated in his paper that the use of appropriate and concrete instructional material is indispensable to ensure that mathematical content is understood by the learners. Similarly, Boaler et al. (2016) emphasized that educators should encourage students' visual approaches and replace the idea that excellent mathematics learners are those who memorize and calculate well. Research has also emphasized that the use of visual representations in mathematics, both for teachers and students, is a necessity in their teaching and learning process (Leinhardt, 1991).

Concrete manipulatives were defined by Bartolini and Martignone (2020, p. 365) as "physical artifacts that can be concretely handled by students and offer a large and deep set of sensory experience". When used in teaching abstract concepts, manipulatives helped in enhancing students' achievement and attitude towards mathematics when used on a long-term basis (Holmes, 2013; Larbi & Okyere, 2014; Sowell, 1989; Uribe-Flórez & Wilkins, 2017). Furthermore, Ojose and Sexton (2019) pointed out that manipulatives' use can deepen the understanding of abstract concepts if it was used along with other teaching methodologies. Specifically, Golafshani (2013) pointed out that manipulatives had been significantly helpful to struggling learners. Because of this, Holmes (2013) and Ramilo et al. (2022) suggested that educational institutions should purchase manipulatives since it contributed to the enhancement of students' learning. Research on the use of manipulatives in teaching mathematics was extended by utilizing it along with other methodologies such as problem-based learning. Meke et al. (2018) argued that problem-based learning and the use of manipulatives were both effective in terms of enhancing students' cognitive abilities in mathematics. Innovations were also made in the use of manipulatives from concrete to virtual manipulatives. Despite these changes, manipulatives in concrete and virtual form both exhibited positive results in terms of supporting students' learning and encouraging relational thinking and algebraic reasoning (Suh & Moyer-Packenham, 2007). These are the reasons why the first author intended to develop an instructional manipulative that will assist teachers in teaching probability. In this way, the learners will be assisted in learning the subject meaningfully. This research concentrated on topics related to probability for Grade 10

students since it was revealed in the baseline data gathering that teachers and students viewed statistics and probability as the most difficult content area.

Theoretical Framework

This research is anchored on Johnson and Lakoff's (2002) Experiential Realism. In this theory, there is a reality "out there" and that our perceptual and cognitive processes serve to represent this reality. This suggests that if we want to provide our students with a meaningful context, we should place them in their own reality. To accomplish this, we must bring the "out there" world into the classroom. This study is also anchored on Realistic Mathematics Education where the contexts and real-life experiences of learners are being utilized as starting points prior to the learning of abstract and formal concepts of mathematics. It also gives opportunities to learners to reinvent their own understanding of the mathematical content and processes through horizontal and vertical mathematization (Barnes, 2005; Gravemeijer, 1994; Van den Heuvel-Panhuizen & Drijvers, 2014).

Methods

In this study, development research method was utilized since it aimed to develop a new instructional manipulative. It was implemented using the Development Research Design anchored on the ADDIE Model (Branch, 2009). Based on the ADDIE Model, this study has two major phases: the gathering and evaluating of the baseline data and the development and evaluation of the manipulative developed. In the first phase, the participants were 35 students and 15 mathematics teachers. They were asked to answer the questions using the baseline interview schedule by Fetalvero (2013) as cited by Malicse et al. (2019). On the other hand, Phase 2 focused on the development and evaluation of the manipulative developed. After the development of the manipulative, 26 Grade 10 Mathematics teachers were asked to evaluate the manipulative using the Evaluation Rating Sheet for Manipulatives as prescribed by the Department of Education (DepEd, 2009). The data collected from the structured interview and questionnaire responses were analyzed using percentages. On the other hand, the evaluation ratings from the mathematics teachers were gathered and statistically analyzed using mean.

Results and Discussion

Baseline Data Report

Based on the results of the survey conducted, the students and teachers have identified statistics and probability as the most difficult content area in Mathematics 10 (students: 40%, teachers: 80%). When asked about their perception on the use of module as the sole instructional material in teaching, 77% of the students disagreed. This implies that students wanted to be engaged in learning using other instructional materials other than their modules. In terms of the mode of teaching the subject and the data gathered shows that 49% of the students preferred to learn mathematics with the aid of the manipulative while 31% and 21% of the students preferred lecture and group activities, respectively.

Frankards: The Developed Manipulative

As shown in Figure 1, here is the developed manipulative, the "Frankards". It is a set of 56 cards specifically crafted to assist teachers in teaching probability concepts. Unlike the

regular deck of cards, Frankards was uniquely designed to use polygons as the card suits instead of the suits in a standard deck of playing card. The use of the standard deck of cards has been banned in schools to prevent students from engaging in gambling-related activities. Hence, an instructional material that is more mathematical than the standard deck of cards was developed.

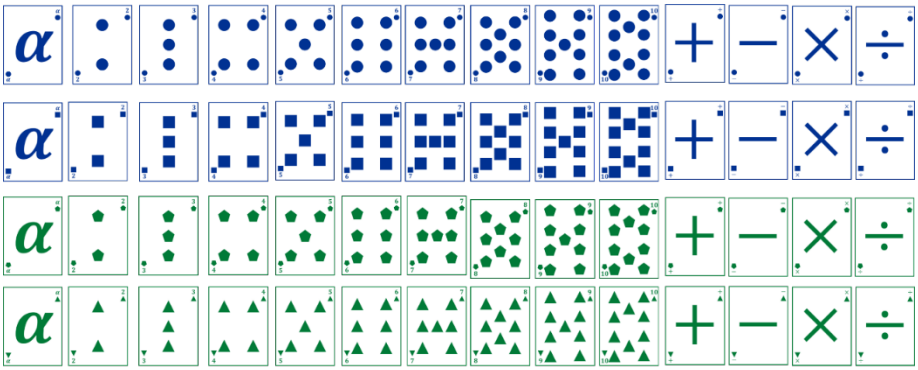

Figure 1: Deck of Frankards (Fran, 2021)

Evaluation of Frankards

Table 1 shows the expert's evaluation of the manipulative in terms of Factor A (Content). It generally shows that the manipulative is formatively evaluated as very satisfactory in terms of content. This implies that the manipulative passed the requirements prescribed for manipulatives as to the content. Specifically, the evaluators have given the manipulative a perfect rating of 4.00 to these indicators: Content reinforces, enriches, and/or leads to the mastery of certain learning competencies for the level and subject it was intended; material has the potential to arouse interest of the target users; and size of the material is appropriate for use in school. Other indicators are also rated very satisfactory signifying that the instructional manipulative is excellent as to content.

Table 1: Experts' Evaluation in Terms of Factor A (Content)

Indicators	Mean Rating	Descriptive Interpretation
1. Content reinforces, enriches, and/or leads to the mastery of certain learning competencies for the level and subject it was intended.	4.00	Very Satisfactory
2. Material has the potential to arouse interest of the target users.	4.00	Very Satisfactory
3. Facts are accurate.	3.76	Very Satisfactory
4. Information provided is up-to-date.	3.60	Very Satisfactory
5. Visuals are relevant to the text.	3.68	Very Satisfactory
6. Visuals are suitable to the age level and interests of the target user.	3.80	Very Satisfactory
7. Visuals are clear and adequately convey the message of the subject or topic.	3.76	Very Satisfactory
8. Typographic layout/design facilitates understanding of concepts presented.	3.88	Very Satisfactory
9. Size of the material is appropriate for use in school.	4.00	Very Satisfactory
10. Material is easy to use and durable.	3.96	Very Satisfactory
Total	38.44	

Note. The indicators are adapted from the Evaluation Rating Sheet for Manipulatives as prescribed by the Department of Education (DepEd, 2009). The following are the equivalent descriptive interpretations for the mean ratings: Very Satisfactory, 3.26 – 4.00; Satisfactory, 2.56 – 3.25; Poor, 1.76 – 2.50; and Not Satisfactory, 1.00 – 1.75.

Table 2 presents the evaluation of experts on the manipulative in terms of Other Findings (Factor B). It further shows that conceptual errors, factual errors, grammatical and/or typographical errors, and other errors are not present as evaluated.

Table 2: Experts' Evaluation in Terms of Factor B (Other Findings)

Indicators	Mean Rating	Descriptive Interpretation
1. Conceptual errors.	4.00	Not Present
2. Factual errors.	4.00	Not Present
3. Grammatical and/or typographical errors.	4.00	Not Present
4. Other errors (i.e., computational errors, obsolete information, errors in the visuals, etc.)	4.00	Not Present
Total	16.00	

Note. The indicators are adapted from the Evaluation Rating Sheet for Manipulatives as prescribed by the Department of Education (DepEd, 2009). The following are the equivalent descriptive interpretations for the mean ratings: Not Present, 3.26 – 4.00; Present but with very minor and must be fixed, 2.56 – 3.25; Present and requires major redevelopment, 1.76 – 2.50; and Poor, 1.00 – 1.75.

Table 3 presents the evaluation of the validators as to instructional and technical design of the manipulative which is rated very satisfactory (3.89). Specifically, the evaluators formatively assessed that the manipulative is safe to use, achieving a perfect rating of 4.00 from the evaluators. The validators also viewed that the size and composition of manipulative is appropriate for the intended audience (3.96). It can be noted that the evaluators formatively assessed the manipulative and rated it very satisfactory across the given indicators for instructional and technical design. This implies that as to the instructional and technical design, the manipulative passed the given criteria.

Table 3: Experts' Evaluation in Terms of Factor C
(Additional Requirements for Manipulatives)

Indicators	Mean Rating	Descriptive Interpretation
Instructional Design		
1. Adequate support material is provided.	3.84	Very Satisfactory
2. Activities are summarized; extension activities are provided.	3.72	Very Satisfactory
3. Suggested activities support innovative pedagogy.	3.92	Very Satisfactory
Technical Design		
4. Manipulative is safe to use.	4.00	Very Satisfactory
5. Size and composition of manipulative is appropriate for intended audience.	3.96	Very Satisfactory
6. Suggested manual tasks within the activities are compatible with the motor skills of the intended users.	3.92	Very Satisfactory
Total	23.36	

Note. The indicators are adapted from the Evaluation Rating Sheet for Manipulatives as prescribed by the Department of Education (DepEd, 2009). The following are the equivalent descriptive interpretations for the mean ratings: Very Satisfactory, 3.26 – 4.00; Satisfactory, 2.56 – 3.25; Poor, 1.76 – 2.50; and Not Satisfactory, 1.00 – 1.75.

Figure 2 shows the summary of ratings of the evaluators across the areas for evaluation. It shows that the earned points for every factor are above the required minimum points reflected as follows: Factor A (Content)=38.44; Factor B (Other Findings) = 16.00; and Factor C (Additional Requirement for Manipulatives) = 23.36. This implies that the manipulative passed the requirements prescribed by the Department of Education for Manipulatives.

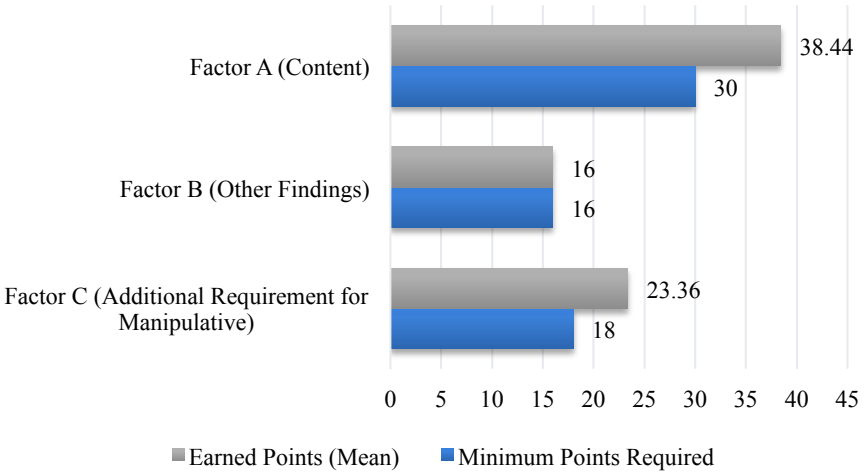

Figure 2: Summary of Ratings for the Areas of Evaluation

Conclusion

It can be inferred that the instructional material developed passed all the prescribed criteria set by the Department of Education in the selection of the appropriate and quality instructional material such as manipulatives. Consequently, the utilization of the instructional material is highly recommended. This is suggested to be the next phase of the study. After testing its effectiveness, it can be recommended for dissemination to teachers especially those who are handling subjects that deal with probability and statistics. The research output can be utilized as an instructional material in teaching probability. Corollary to this, the instructional material is recommended to be submitted to the Intellectual Property Office of the Philippines for Copyright Application. Initial processes had been conducted by the researcher in relation to the intellectual property rights of the owner and the university. In relation to its dissemination and utilization, the effectiveness of this instructional material should be tested first. Thus, it is recommended to conduct future research focusing on testing the effectiveness of this material.

Acknowledgements

The authors extend their heartfelt thanks to Romblon State University, Ateneo de Manila University, and Department of Science and Technology-Science Education Institute.

References

Bartolini, M. G., & Martignone, F. (2020). Manipulatives in mathematics education. *Encyclopedia of mathematics education*, 487-494. https://doi.org/10.1007/978-3-030-15789-0_93

Barnes, H. (2005). The theory of Realistic Mathematics Education as a theoretical framework for teaching low attainers in mathematics. *Pythagoras, 2005*(61), 42-57.

Branch, R. M. (2009). *Instructional design: The ADDIE approach* (Vol. 722). New York: Springer.

Braza, M. T., & Supapo, S. S. (2014). Effective Solutions in the Implementation of the K to12 Mathematics Curriculum. *West Visayas State University. Iloilo City*.

Boaler, J., Chen, L., Williams, C., & Cordero, M. (2016). Seeing as understanding: The importance of visual mathematics for our brain and learning. *Journal of Applied & Computational Mathematics*, *5*(5), 1-6.

Department of Education (2009). Guidelines and Processes for LRMDS Assessment and Evaluation.

Fran, F. A. (2021, July). Analyzing students' achievement and attitude through the Frankards context in learning probability. In *Journal of Physics: Conference Series* (Vol. 1957, No. 1, p. 012010). IOP Publishing.

Gafoor, K. A., & Kurukkan, A. (2015). Why High School Students Feel Mathematics Difficult? An Exploration of Affective Beliefs.

Golafshani, N. (2013). Teachers' beliefs and teaching mathematics with manipulatives. *Canadian Journal of Education/Revue canadienne de l'éducation*, *36*(3), 137-159. Retrieved from https://www.jstor.org/stable/canajeducrevucan.36.3.137

Gravemeijer, K. P. E. (1994). *Developing realistic mathematics education*.

Holmes, A. B. (2013). Effects of Manipulative Use on PK-12 Mathematics Achievement: A Meta-Analysis. *Society for Research on Educational Effectiveness*.

Johnson, M. & Lakoff, G. (2002). *Why cognitive linguistics requires embodied realism*, *13*(3), 245-263. https://doi.org/10.1515/cogl.2002.016

Larbi, E., & Okyere, M. (2014). Algebra tiles manipulative and gender differences in learning and achievement in mathematics: A case of Sunyani West Municipality. *Journal of Education and Practice*, *5*(38).

Leinhardt, G. (1991). Where subject knowledge matters. *Advances in Research on Teaching*, *2*, 83-113.

Malicse et al. (2019). Development and Formative Evaluation of Biocomics in Genetics

Meke, K. D. P., Wutsqa, D. U., & Alfi, H. D. (2018, September). The effectiveness of problem-based learning using manipulative materials approach on cognitive ability in mathematics learning. In *Journal of Physics: Conference Series* (Vol. 1097, No. 1, p. 012135). IOP Publishing. https://doi.org/10.1088/1742-6596/1097/1/012135

Moyer, P. S. (2001). Are we having fun yet? How teachers use manipulatives to teach mathematics. *Educational Studies in mathematics*, *47*(2), 175-197.

Ojose, B., & Sexton, L. (2009). The effect of manipulative materials on mathematics achievement of first grade students. *The mathematics educator*, *12*(1), 3-14.

Ramilo, R., Cruz, M. P., Geanga, J. P. D., & Faustino, J. B. (2022). Teachers' perspectives on optimizing manipulatives in teaching 21st century skills in kindergarten. *Journal of Childhood, Education & Society*, *3*(1), 1-11. https://doi.org/10.37291/2717638X.20223198

Sowell, E. J. (1989). Effects of manipulative materials in mathematics instruction. *Journal for research in mathematics education*, *20*(5), 498-505. https://doi.org/10.5951/jresematheduc.20.5.0498

Suh, J., & Moyer-Packenham, P. (2007). Developing students' representational fluency using virtual and physical algebra balances. *Journal of Computers in Mathematics and Science Teaching*, *26*(2), 155-173. Retrieved from https://www.learntechlib.org/primary/p/22799/

Uribe-Flórez, L. J., & Wilkins, J. L. (2017). Manipulative use and elementary school students' mathematics learning. *International Journal of Science and Mathematics Education*, *15*(8), 1541-1557. https://doi.org/10.1007/s10763-016-9757-3

Van den Heuvel-Panhuizen, M., & Drijvers, P. (2020). Realistic mathematics education. *Encyclopedia of mathematics education*, 713-717.

Vinson, B. M. (2001). A comparison of preservice teachers' mathematics anxiety before and after a methods class emphasizing manipulatives. *Early Childhood Education Journal*, *29*, 89-94.

Contact email: frankie.fran@obf.ateneo.edu
cvistro-yu@ateneo.edu