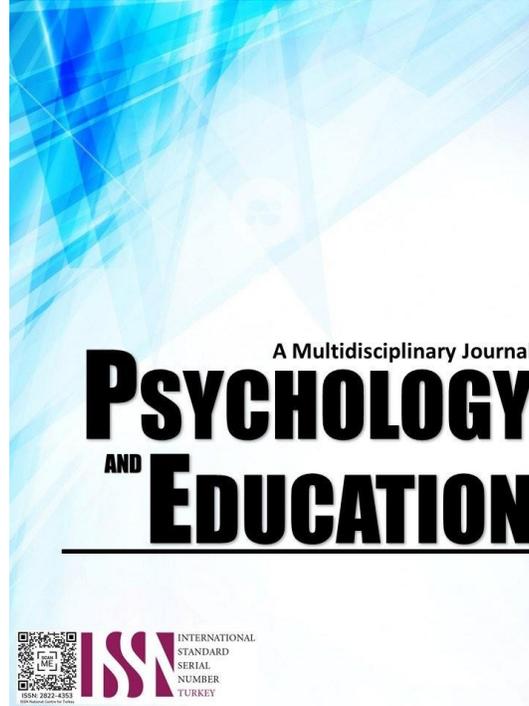


CONSTRUCTION AND VALIDATION OF A SCALE ON THE DIFFERENT SOURCES OF CONCEPTUAL UNDERSTANDING OF CONIC SECTIONS



PSYCHOLOGY AND EDUCATION: A MULTIDISCIPLINARY JOURNAL

Volume: 16

Issue 8

Pages: 903-908

Document ID: 2024PEMJ1511

DOI: 10.5281/zenodo.10571085

Manuscript Accepted: 01-06-2024

Construction and Validation of a Scale on the Different Sources of Conceptual Understanding of Conic Sections

Janwin C. Magas,* Dominga C. Valtoribio

For affiliations and correspondence, see the last page.

Abstract

A conceptual understanding of mathematics will aid students in solving mathematical problems and is their starting point. The study's findings provide necessary information on the different sources such as teachers, the internet, modules, parents, and students' own metacognition in developing students' conceptual understanding of conic sections. As a result, this study is a quantitative study that aims to construct and validate an instrument that can be used to determine the extent to which the different sources help develop students' conceptual understanding. The study included 107 high school students and 2 mathematics content specialists. Exploratory factor analysis (EFA) was conducted for data reduction. The result of the exploratory factor analysis resulted in the removal of 14 items. Four items (19, 20, 24, and 48) failed to load on any dimension significantly, while 10 items (13, 16, 37, 38, 39, 40, 41, 42, 45, and 49) loaded onto factors other than their underlying factors. The final form of the instrument has 35 statements that are designed to determine the extent of different sources of conceptual understanding such as teacher, module, internet, parents, and own metacognition in learning conic sections. 10 statements under "teacher" as a source of conceptual understanding, 6 for the module, 9 under the internet, 6 under parents, and 4 statements under own metacognition. The scale has an overall Cronbach's Alpha of 0.93.

Keywords: *conceptual understanding, conic sections, own metacognition, exploratory factor analysis*

Introduction

Studying mathematics requires in-depth knowledge to be able to solve problems. Students often regard it as one of the most difficult subjects to deal with and unfortunately, only a few are interested in studying it. To understand mathematics, one should be able to understand patterns either logically or geometrically. Conceptual understanding is a must to be able to establish the required steps to be able to solve certain problems. One example is in terms of studying conic sections. For the students to understand any of the conic sections, they must be able to understand the different patterns such as translating the center $(0,0)$ to (h,k) . They must have enough conceptual understanding to be able to see relationships or patterns and be able to represent, estimate, and apply them in real-life situations.

On the other hand, teachers play a very important role in developing and enhancing the conceptual understanding of the students in Mathematics. They must possess in-depth knowledge of the discipline and show mastery of the lesson to be able to meet the needs and demands of the students.

In developing the conceptual understanding of the students especially in dealing with the conic sections, teachers' mastery of the subject matter and ability to effectively impact the knowledge of the students are the major rudiments expected from them. Hence, teachers can be the source of conceptual understanding for the students in dealing with Mathematics, particularly in Pre-Calculus because those topics require students and even the teachers to think analytically or even logically to better understand the concepts.

Conic sections were chosen as the study's topic anchor because students found it difficult to solve issues involving circles, parabolas, ellipses, and hyperbolas. A study conducted by Edillo (2021) among Grade 11 students at Linao National High School found that the students knew very little about conic sections. The researchers chose the competency based on the students' poor performance in previous years.

Furthermore, even overseas students have had difficulty dealing with conic sections. According to Sudihartinih and Purniati (2019), the students were unable to determine the description of a simple parabola equation, the equations of the conic, the length of the latus rectum of an ellipse, and a simple equation of asymptote of hyperbola, despite knowing its vertices points.

With the aforementioned studies, it is critical to conduct this study to provide teachers, curriculum developers, and other stakeholders with in-depth analysis and possible solutions to the long-standing concern about student performance in conic sections, as well as other topics under mathematics as the discipline that is always included in national and international assessments.

Research Objectives

The study aimed to construct and validate an instrument on the different sources of conceptual understanding such as teachers, modules, the internet, parents, and students' own metacognition using exploratory factor analysis to determine the extent of these sources in

developing students' conceptual understanding of conic sections.

Literature Review

Students show conceptual understanding in mathematics when they can recognize, label, and generate examples of concepts; use and interrelate models, diagrams, manipulatives, and various representations of concepts; identify and apply principles; know and apply facts and definitions; compare, contrast, and integrate related concepts and principles; recognize, interpret, and apply the signs, symbols, and terms used to represent concepts. Conceptual understanding measures a student's ability to reason in situations that require the careful application of concept definitions, relations, or representations of either (Al-Mutawah et al., 2019).

Conceptual understanding can come from a variety of sources. The materials used by teachers, the availability of the internet, the extent to which parents assist their children in dealing with mathematics, the significant roles of teachers in developing students' conceptual understanding, and students' metacognition in the discipline are all covered in this study. Furthermore, the figure illustrates the importance of teachers, modules, the internet, parents, and students' metacognition in assisting students in becoming conceptually equipped so that they can become more proficient in dealing with Pre-Calculus, particularly Conic Sections.

According to an OECD study, "of those variables, potentially open to policy influence, factors related to teachers and teaching are the most important influences on student learning." International evidence suggests that a succession of good teachers can offset the deficiencies associated with poor school preparation. Other research has found that teacher education quality and instruction are more strongly associated with student accomplishment than class size, overall spending levels, or teacher salaries (Ambussaidi & Yang, 2019).

According to Magas (2022), students exhibit low conic section competency because they are unfamiliar with the concepts covered. However, he indicated that employing modules can help students increase their competency in the topic, as long as the module is correctly created based on the student's capacity to understand Mathematics, particularly conic sections.

Internet access can impact a variety of talents, including academic accomplishments and cognitive abilities. If children do not have access to educational resources, an internet connection may help them acquire academic skills by giving them access to educational websites with subject-specific content and exercises (e.g., Khan Academy). Furthermore, youngsters have access to e-books as well as other reading resources such as newspapers, blogs, and online encyclopedias (for example, Wikipedia). On the other hand, internet access may reduce learning if youngsters spend more time doing activities that are not conducive to academic skill development, such as playing online games, and less time reading and doing homework. Finally, internet access may have an impact on cognitive abilities by exposing children to online activities that modify cognitive processes (Mills, 2014, quoted in Malamud, Cueto, & Cristia, 2018).

Several studies have found a link between parental participation and academic attainment. Parental engagement refers to the circumstance in which parents are directly active in their children's education. However, there are many various elements to parental engagement, such as the sense of support, organization, enthusiasm in the educational process, expectations, school relationships, and time for homework assistance (Veas et al., 2018).

In the case of mathematics, teachers may suggest to parents how to handle their children's challenges during homework to build their self-regulation performance and perseverance in dealing with mathematical tasks (Panaoura, 2017). According to Güner and Erbay (2021), pupils with strong metacognitive abilities are more likely to answer problems successfully by employing appropriate techniques, mathematical notations, and logical reasoning. The findings also demonstrated that students with low metacognitive skills struggle to understand the problem, choose acceptable techniques, and locate the proper answer.

According to Meyer (2018), conceptual understanding refers to an integrated and functional grasp of mathematical ideas. Students with conceptual understanding know more than isolated facts and methods. They understand why a mathematical idea is important and the kinds of context in which it is useful. They have organized their knowledge into a coherent whole, which enables them to learn new ideas by connecting those ideas to what they already know. Conceptual understanding also supports retention. Because facts and methods learned with understanding are connected, they are easier to remember and use, and they can be reconstructed when forgotten.

In connection with the aforementioned literature, studying Pre-Calculus requires students to have prerequisite knowledge in geometry and even algebra. They must be able to see relationships or patterns to be able to understand the conic sections. Moreover, teachers are challenged to help the students develop their conceptual understanding not just in pre-calculus but even in other disciplines. It is through them that the students can gain knowledge on how to deal with the discipline and eventually become good at it. Soyke (2016) stated that conceptual understanding refers to the notion that a student is not just taught how to do math but also the why behind it.

Students are encouraged to see the bigger framework that underlies all math topics and to think fluidly so that they can apply their math skills to a wide variety of problems. According to Sbar (2018), conceptual understanding in mathematics is the creation of a robust framework representing the numerous and interwoven relationships between mathematical ideas, patterns, and procedures. This framework can be used to coherently integrate new knowledge and solve unfamiliar problems.

If the students possess conceptual understanding, especially in mathematics, they can understand even concepts that require deeper understanding. It is simply because conceptual understanding will allow students to investigate and analyze problems to be able to establish the proper procedures to solve the problem.

According to Minarti and Wahyudin (2019), a conceptual understanding of mathematics will help and is the initial capital of students in solving mathematical problems. It goes to say that for students to be able to solve problems, they must develop their conceptual understanding. This implies as well that conceptual understanding is the foundation of mathematical reasoning for the students. As such, teachers in mathematics should think of ways to develop the conceptual understanding of the students.

As cited by Malatjie and Machaba (2019), Kharatmal (2009) refers to conceptual understanding as connections of mathematics ideas that are not disconnected from one another. This implies that a learner has a conceptual understanding when he or she can explain, describe, and apply the same concept in different ways and different situations. This further refers to a situation where a learner can see the integration of concepts understanding takes place when mathematical concepts are not isolated. The different literature above suggests that when it comes to studying mathematics, one should not just focus on the “how” but on the “what” of the problem. This means that for the students to solve problems, they must be able to analyze, see patterns, and think logically.

Methodology

This quantitative study attempts to investigate the relationship between the variables included. It is appropriate to use since the exploratory factor analysis considers determining the relationships among variables. Creswell (2014) defines quantitative research as a method for testing objective theories by examining the relationship between variables.

Participants

The study was conducted in Cauayan City, Philippines. A total of one hundred seven (107) selected high school students and two (2) Mathematics content specialists participated in the study.

Instruments

This study did not use any instrument but rather developed a scale on the different sources of conceptual understanding of conic sections. However, as a first step towards the development of a scale on the different sources of conceptual understanding among students in learning conic sections, 10 statements in each source namely teacher, module, internet, parents, and own metacognition, on a 4-point Likert scale were written after a careful study of related literature and studies. A total of 50 statements were constructed for the first trial of the scale which was administered among the high school students of a school in Cauayan City, Isabela, Philippines.

Procedure

The researchers were guided by the following procedures: (1) Asked for approval from the school heads to conduct this study. (2) The Mathematics content specialists were asked to evaluate the scale and give their comments and suggestions for content validity purposes. After collecting all the data, it was tallied, analyzed, and interpreted. (3) After constructing a total number of 50 statements, the scale was submitted to the experts for content validation. Two Mathematics experts gave their comments and suggestions on the scale constructed. Although it is not included in the context of this study the classifications or qualifications of experts who will validate the scale, those two Mathematics teachers can be considered experts because they are actively involved in conducting studies in Mathematics and they have been teaching the discipline for a long time. The first expert has been teaching Mathematics for 20 years and the second expert has been teaching Mathematics and other subjects related to education for 30 years. After editing the instrument based on the comments and suggestions of the experts, it was administered among one hundred seven (107) high school students.

After collecting the responses of the students included in this study, EFA was performed using the principal component analysis and varimax rotation. The minimum factor loading criteria were set to 0.50. The communality of the scale, which indicates the amount of variance in each factor, was also determined to ensure an appropriate level of explanation.

Another important step that needs to be done is to determine if the assumptions for EFA were satisfied. In this case, Bartlett’s test of sphericity, which provides a measure of the statistical probability that the correlation matrix has a significant correlation among some of its components, was determined. The results were significant, , which indicates the appropriateness of the data for factor analysis. Furthermore, the Keiser-Meyer-Olkin measure of sampling adequacy (MSA), which indicates the appropriateness of the data for factor analysis, was 0.827. In this case, it is considered appropriate for factor analysis since it is greater than 0.800.

The result of the initial EFA resulted in the removal of 14 items. Four items (19, 20, 24, and 48) failed to load on any dimension significantly, while 10 items (13, 16, 37, 38, 39, 40, 41, 42, 45, and 49) loaded onto factors other than their underlying factors.



Ethical Considerations

The research participants were not in any way harmed during the study. Their dignity was respected, so no names were mentioned in the exam results table or during the subsequent discussion. Data confidentiality was ensured.

Results and Discussion

The Final Form of the Instrument

The final form of the instrument has 35 statements that are designed to determine the extent of different sources of conceptual understanding such as teacher, module, internet, parents, and own metacognition in learning Pre-Calculus. 10 statements under “teacher” as a source of conceptual understanding, 6 for the module, 9 under the internet, 6 under parents, and 4 statements under own metacognition. The scale has an overall Cronbach’s Alpha of 0.93.

After the initial exploratory factor analysis (EFA) where 14 items were removed, the researchers repeated the EFA without including those items. The Kaiser-Meyer-Olkin MSA was 0.873. Bartlett’s Test of sphericity proved to be significant and all communalities were over the required value of 0.500. Factor 1 includes items Q1-Q10, referring to a teacher as a source of conceptual understanding. Factor 2 includes items Q11, Q13-Q15, and Q17- Q18, referring to module. Factor 3 includes items Q21-Q23, and Q25-Q30, referring to the internet. Factor 4 gathers items Q31-Q36. Factor 5 includes items Q43, Q44, Q46, and Q47. Factor loadings are presented in Table 1.

Items	Factor				
	1	2	3	4	5
Teacher					
Q1	0.606				
Q2	0.666				
Q3	0.736				
Q4	0.811				
Q5	0.694				
Q6	0.734				
Q7	0.714				
Q8	0.790				
Q9	0.713				
Q10	0.723				
Module					
Q11		0.656			
Q12		0.711			
Q14		0.579			
Q15		0.674			
Q17		0.634			
Q18		0.714			
Internet					
Q21			0.611		
Q22			0.735		
Q23			0.663		
Q25			0.749		
Q26			0.770		
Q27			0.750		
Q28			0.685		
Q29			0.695		
Q30			0.771		
Parents					
Q31				0.772	
Q32				0.840	
Q33				0.838	
Q34				0.781	
Q35				0.821	
Q36				0.768	
Own Metacognition					
Q43					0.687
Q44					0.830
Q46					0.727
Q47					0.825

The reliability of the scale was also determined using Cronbach's Alpha. The overall reliability of the instrument was 0.93 indicating an excellent; high to very high; or adequate value for individual measurement and diagnosis, which is acceptable (Hedden, 1997). Furthermore, the reliability of each factor is presented in Table 2.

<i>Sources of conceptual understanding</i>	<i>Cronbach's Alpha</i>	<i>Interpretation (Hedden, Steve, 1997)</i>
Teacher	0.93	Excellent
Module	0.88	Excellent
Internet	0.91	Excellent
Parents	0.91	Excellent
Own metacognition	0.81	Good

The table shows Cronbach's alpha of each source and the corresponding interpretation. The reliability of the scale was determined after the EFA, and as stipulated in the table, the reliability of each source is acceptable. Hence, the scale can be used as an instrument for gathering the necessary information that can help improve the performance of the students, especially in conic sections. See the appendix for the final statements of each factor.

Conclusion

Students require conceptual comprehension skills as essential learning to solve problems and develop information from varied experiences or prior understanding. To learn mathematics successfully, each learner must be mathematically conversant (Ningrum et al., 2022). However, other issues arise when considering students' performance, notably in Mathematics, particularly in the Philippines, where poor academic achievement is always a major worry. Therefore, this research was carried out to provide information on how students' conceptual comprehension, particularly of conic sections, might be developed. The study's findings show that the scale, which consists of multiple items, can be used as an instrument to assess the extent to which teachers, the internet, modules, parents, and students' own metacognition aid in the development of students' conceptual grasp of conic sections. The instrument or scale is supposed to alleviate the long-standing worry of low academic achievement, particularly in conic parts.

References

- Al-Mutawah, M. A., Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual understanding, procedural knowledge and problem-solving skills in mathematics: High school graduates work analysis and standpoints. *International Journal of Education and Practice*, 7(3), 258–273. <https://doi.org/10.18488/journal.61.2019.73.258.273>
- Ambussaidi, I., & Yang, Y.-F. (2019). The Impact of Mathematics Teacher Quality on Student Achievement in Oman and Taiwan. *International Journal of Education and Learning*, 1(2), 50–62. <https://doi.org/10.31763/ijelev.1i2.39>
- Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. (4th ed.). Los Angeles, CA: Sage.
- E. D. Minarti and Wahyudin, Conceptual understanding and mathematical disposition of college student through concrete-representational-abstract approach (CRA), *Journal of Physics: Conference Series* 1157: 042124, 2019.
- Edillo, G. L. (2021). IMPROVING STUDENTS PERFORMANCE IN SOLVING PROBLEMS ON EQUATION OF CONIC SECTIONS THROUGH POLYA'S APPROACH. 10(7). www.garph.co.uk
- Güner, P., & Erbay, H. N. (2021). Metacognitive Skills and Problem-Solving. *International Journal of Research in Education and Science*, 715–734. <https://doi.org/10.46328/ijres.1594>
- Magas, J. C. (2022). The Impact of Personalized Module to the Grade 10 Students in Learning Pre-Calculus: A Case Study of a School in Cauayan City, Philippines. *Journal of Science and Mathematics Education in Southeast*, 45.
- Malamud, O., Cueto, S., & Cristia, J. (2018). Do Children Benefit from Internet Access? Experimental Evidence from a Developing Country.
- Malatjie, F., & Machaba, F. (2019). Exploring mathematics learners' conceptual understanding of coordinates and transformation geometry through concept mapping. *Eurasia Journal of Mathematics, Science and Technology Education*, 15(12), 1–16.



<https://doi.org/10.29333/EJMSTE/110784>.

Meyer, D. (2018). What is conceptual understanding? Retrieved 2022 from <https://davidwees.com/content/what-is-conceptual-understanding/#:~:text=According%20to%20Adding%20It%20Up,in%20which%20is%20it%20useful>.

Rita Panaoura. (2020). Parental Involvement in Children's Mathematics Learning Before and During the Period of the COVID-19. *Social Education Research*, 65–74. <https://doi.org/10.37256/ser.212021547>

Sbar, E. (2018). Schemas are key to deep conceptual understanding. Retrieved 2022 from <https://blog.mindresearch.org/blog/schemas-deep-conceptual-understanding>

Soyke, J. (2016). Conceptual understanding in math. Retrieved 2022 from <https://demmelearning.com/blog/conceptual-understanding/>

Sudihartinih, E., Indonesia, U. P., Purniati, T., & Indonesia, U. P. (2020). Students' Mistakes and Misconceptions on the Subject of Conics. *International Journal of Education*, 12(2), 92–100. <https://doi.org/10.17509/ije.v12i2.19130>

Affiliations and Corresponding Information

Janwin C. Magas, PhD(c)

Saint Mary's University – Philippines

Dominga C. Valtoribio, PhD

Saint Mary's University – Philippines