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POST-SECONDARY STUDENTS COMMUNICATE ABOUT DEFINITE INTEGRAL

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ABSTRACT

Student challenges in learning definite integral are among one of the main issues in calculus. Several cognitive barriers have been identified that cause problems for students when learning for the first time about the single function of the integral. Theory based on radical constructivism is the central pillar in the discussion of this article, and it focuses on the sub-constructs of communication, which identify the description or interpretation essential to students in the definite integral. Students are required to communicate and interpret meaningful sentences that involve the analysis of situations in everyday life. In addition, students also need to communicate by constructing appropriate mathematical sentences according to the information given. There are two categories in communication: the ways students communicate by creating a description that involves definite integrals and how students form sentences from descriptions that involve definite integrals. A case study is the design for the study. The method of selecting respondents is through purposive sampling, which is to choose six second-semester diploma students at technical higher education institutions in the Selangor area, especially those who follow the primary field of technical engineering. The study results show that post-secondary students' understanding of definite integrals certainly involves how they communicate with friends who cannot attend class to learn about definite integrals, which is analyzed based on three categories: mathematical language, skills, and graphics.

Keywords: definite integral; clinical interview; communication; understanding; constructivism

Introduction

Poor essential calculus and negative perception of calculus must be addressed as well, and proper planning and approach in introducing the learning of calculus would be too risky for students' future understanding of subjects related to calculus (Tuan Salwani & Effandi, 2015). According to Abadi and Fiangga (2018), students must understand the concept of learning calculus to solve integral problems. In addition, calculation techniques and formulas, especially in integral calculus, are among the main reasons students struggle to learn calculus (Ferrer, 2016). In Smart's (2010) study on student understanding in calculus, most students showed symbolic understanding but with a minimal understanding contained in specific tasks. Christian S et al. (2022) found that Basic Calculus is difficult, especially along integrals; some of the difficulties experienced by the students were a lack of knowledge of the concepts, poor application, complicated formulas and processes, and confusion in understanding the problem. Students feel they do not need to understand calculus concepts because routine questions repeatedly appear and become a habit for post-secondary students in Malaysia, making them automatically know how to solve them without knowing the meaning behind the question (Romeo, 2020).

Syed Uzma et al. (2023) mentioned that to have a learning environment, students and teachers should chat with each other, and communication is not possible without language, coupled with communication competence that needs to be mastered the four skills of speaking, listening, reading, and writing to thrive in your career. Effective communication supported by visuals coupled with textual information can produce significantly positive learning outcomes, especially for students who find the content interesting and authentic. (Jamal & Mustafa, 2023). Therefore, the researcher has chosen the difficulty of communicating the concept of definite integral among post-secondary students because it offers an opportunity to discuss significant problems related to the description, interpretation, and arguments used by students in learning definite integral among themselves in class.

The purpose of this research was to identify how post-secondary students communicate in situations that involve definite integrals. Specifically, this answers the question: How do post-secondary students communicate in situations that involve definite integrals? Therefore, this study aims to explore how post-secondary students communicate in situations involving definite integral.

Literature Review

In this study, communication is one of the sub-constructs of student understanding according to the Radical Constructivism theory, which will be discussed in this article. The term communication for this study refers to an individual's interaction with the environment, whether the physical, social, or cultural environment, involves an empirical abstraction from which knowledge is derived directly from external objects (Nik Azis, 1999). Von Glasersfeld (1991) also stated communication is a language image that transfers thought, meaning, knowledge, or information from one speaker to another. In this study, communication characteristics in the understanding of post-secondary students about the studied definite integral are based on specific interests because it reveals that language users must construct the meaning of words, phrases, sentences, and texts individually (Von Glasersfeld, 1996).

In this century, there needs to be more previous research on how students communicate with their peers about definite integral. There is only one research from the master's thesis obtained by the researcher, which is the study from Dina and Zolkepeli (2015), which studied the effectiveness of 73 students in one the secondary schools in Indonesia who were divided into a treatment group and a control group, using the Autograph software in the way they communicate and their level of achievement on integral topics, which are finding area and volume of rotation which is generated for four weeks. A quasi-experiment is a methodology used in their study. The research instruments were a communication skills test, math and achievement tests, and student activity sheets. Collected data is quantitative from pre and post-tests. There are two tests that Dina and Zolkepeli (2015), which is a t-test to see the difference between skills in student communication and their achievement on the topic, and a Correlation test, Bevariate, to see the relationship between the variables that exist between two groups. The results show a significant difference in mathematical communication skills and student achievement between a treatment group that uses Autograph software and a control group that does not. Their study's results also show a relationship between mathematical communication skills and achievement in student mathematics.

In conclusion, from Dina and Zolkepeli's (2015) study, students who can communicate mathematically can generate mathematical ideas from mathematical problems, which makes them able to think of strategies that are used accurately together with friends and math teachers in the class. Indirectly, this can increase their mathematical achievements, especially on the definite integral. In this research, the researcher conducted a study on how post-secondary students communicate with friends about definite integral, how to communicate with friends about the broad area under the curve graph, and how to communicate with friends about how to solve definite integral questions.

Methodology

A case study as a research design is carried out on second-semester students who are pursuing a diploma in engineering. A total of six students were interviewed. Qualitative data was chosen because several data collection methods were used in this study, including clinical interviews, classroom observations, notes made by the researcher, and some notes and images made by the study participants. From the literature review carried out, the instrument for the Rosken & Rolka (2007) study has been adapted in this article, where the role of the concept of image and the concept of definition for students studying integral calculus is studied. The instrument for the study of Jones (2010) is also used to study students' understanding of integral and how that knowledge is applied in physics and engineering.

Three clinical interview plans have been implemented, but only the third interview plan is related to the sub-construct of understanding: Communication. In the Third Interview Plan, one of the objectives stated is to identify how post-secondary students communicate with their peers in the class about inclusive learning in definite integral. The third interview plan has two main parts designed by the researcher, which are the method of the study participants communicating about definite integrals and how they solve definite integral problems, which includes three subtasks in their way of communicating and five subtasks in problem-solving. Protocol 5.1 involved how the participants communicated with friends who could not attend the integration class. They are asked to tell the concept and definition of definite integral and indefinite integral. Next, they were asked to state how to communicate with their classmates using mathematical ideas about integration, which, of course, includes giving verbal and non-verbal views, making references from mathematics textbooks, showing mathematical work or activities, and using tools and technology in learning mathematics (Nik Azis, 2014). Next, Protocol 5.2 involves the participants' communication about the area under the curve. In this Protocol, the student was asked to tell about his friend who could not attend the integral class on the concept of the area under the curve and the concept of how to find the sum of the area of each trapezoid shape drawn under the curve graph.

Four levels of data analysis were conducted in this study. In the first stage, the researcher observes the video recordings, listens to the voice recorder, and transcribes them using a written protocol. This transcription covers the interaction between the researcher and the participants during the interview session and the researcher's notes during and after the interview. In the second stage, the raw data were organized, arranged in transcription, and processed according to specific themes and subthemes to produce a written protocol. In the third stage, a case study is prepared for each study participant using the information obtained from the transcription. Finally, coding was done to clarify the written text, and observations were recorded for each study participant in each protocol designed. This was followed by categorizing it into sub-constructs of understanding and definite integral subconstructs.

Result

Post-secondary students' understanding of definite integral communication with their friends who could not come to school on the day their teacher taught the topic of integration, and their statements were analyzed based on three main questions, which are communication with a friend about definite integration, communication with a friend about the area under a curve graph, and communication with friends about how to solve definite integration questions.

Communicate about Definite Integral

Connecting with the students' way post-secondary students communicate with their peers about definite integrals, participants used three categories, which are communication-based on language mathematics, skill-based communication, and graphic-based communication in communicating with friends about definite integrals. Description for the three categories are:

(i) Communication is based on Mathematical Language. There are two types of responses:

a. Students communicate to find similarities in function gradients
b. Students communicate by drawing and shading the area under the bounded curve graph widely, beginning with the lower limit and ending with an upper limit on the xy-plane.

(ii) Communication is based on Skills. There are two types of responses:

a. Students communicate by showing the way of using the fundamental theorem of calculus, i.e., if f, is continuous in interval $[a, b]$ and the function F is the antiderivative of f in $[a, b]$, then $\int_a^b f(x)dx = F(b) - F(a)$, where a is called the lower limit and b called the upper limit of the integral.
b. Students communicated by showing how to use numerical integrals from the tips of the trapezium and by drawing several trapezoidal shapes below the graph curve. Then, the area of each trapezium is found by using the formula for the area of the trapezium and getting the sum of the areas of all trapezoids to find the area under the curve.

(iii) Graphical communication. There are three types of responses:

a. Students communicate by sketching curve graphs on *xy*-plane.
b. Students communicate by shading the area under the graph.

c. Students communicate using definite integral symbols, which is $\int_a^b f(x)dx$ or $\int_c^d f(y)dy$.

Table 4.8 summarizes three categories of communication with friends about the definite integral: mathematical language, skills, and graphics, by participants when they give interpretations involving activities for communication about the definite integral.

Table 1: Communicate about Definite Integral

Category	***Description***	***Participants***
(i) Communication is based on Mathematical Language	Anti-derivative	Hamim, Zalikha, Nurin
	Find distance velocity from acceleration.	Hamim, Zalikha,
	The equation of the gradient function	Hamim, Nurin
(ii) Communication is based on Skills	The area under the curve graph.	Hamim, Zalikha,
	Working on the Fundamental of Theorem Calculus	Farid, Zalikha, Maria, Amir, Nurin
	Working on the Trapezoidal Rule	Farid
(iii) Graphical communication	Draw the graph of the curve on the xy-plane.	Farid, Zalikha, Maria
	Shade the area under the graph curve in the xy-plane	Farid, Zalikha, Maria,
	Using the definite integral symbol ie abfxdx or cdfydy.	Farid, Hamim, Zalikha, Amir, Nurin

There are two categories in the research results obtained. In dominant communication, five out of six participants chose to use skill categories and graphics to communicate with friends who cannot come to school about definite integral. They are more inclined to communicate by expressing the symbol of the definite integral, $\int_a^b f(x)dx$ on the x-axis or $\int_c^d f(y)dy$ on the y-axis. Each definite integral symbol, meaning, and purpose are explained individually. Friends better understand their justification by using examples of definite integral questions as symbols of definite integral and teaching their friends how to integrate a function.

Communication about the Area under a Curve

In the way post-secondary students communicate with their friends about the area under the curve, the participants used two categories, which are graphics and skills in communicating with friends. Description of the two categories is:

(i) Graphical communication. There are three types of responses:
  a. Draw the graph of the curve on the xy-plane
  b. Shade the area area on the xy-plane
  c. Draw some trapezoidal shapes on the xy-plane

(ii) Communication is based on Skills. There are two types of responses:
  a. Working on the Fundamental of Theorem Calculus
  b. Working on the Trapezoidal Rule

An analysis of communication techniques for post-secondary students and their friends regarding the area under the curve graph is shown in Table 2. The schedule shows two categories for communication methods: a description of the category and participants who use the category.

Table 2: Communicate about the Area under a Curve

Category	**Description**	**Participants**
(i) Graphical communication	Draw the graph of the curve on the xy-plane.	Farid, Hamim, Zalikha, Amir, Maria
	Shade the area under the graph curve in the xy-plane.	Hamim, Zalikha,
	Draw some trapezoidal shapes on the xy-plane.	Farid, Hamim, Amir, Nurin, Maria
(ii) Communication is based on Skills	Using the Fundamental Theorem of Calculus as an integral	Hamim, Zalikha, Amir
	Using the Trapezoidal Rule, find an approximate solution.	Farid, Hamim, Amir, Nurin, Maria

In conclusion, from the two categories, five were found of the six descriptions to be dominant, of which each consists of five different participants used it. The description is drawing a graph of the curve on the xy-plane, drawing several trapezoidal shapes on the xy-plane, using the fundamental theorem of calculus as a way of integral, and using trapezium tips in finding an approximate solution for a definite integral. Only two participants shaded the area below the curve graph on the xy-plane: Hamim and Zalikha. Generally, participants used graphic and skill categories to communicate with their friends about the area under the curve.

Communication on Solving Definite Integral

In how post-secondary students communicate with their friends about completing the definite integral, the participants used only one category, i.e., communication skills. The description for the category is:

(i) Communication is based on Skills. There are two types of responses:
  a. Working on the Fundamental of Theorem Calculus
  b. Working on the Trapezoidal Rule

An analysis of communication methods for post-secondary students to their friends about how to solve the definite integral is shown in Table 3, which includes two categories for the way study participants communicate, descriptions for those categories, and participants who use the category.

Table 3: Communicate on Solving Definite Integral

Category	Description	Participants
(i) Communication is based on Skills	Using the Fundamental Theorem of Calculus as an integral	Farid, Hamim, Maria, Amir, Nurin
	Using the Trapezoidal Rule, find an approximate solution.	Hamim, Zalikha, Maria, Nurin

A dominant description of how to communicate with friends about how to solve definite integral problems by using the Fundamental Theorem of Calculus as a way of doing integral. Five participants tended to use the Fundamental Theorem of Calculus because it is easier to understand and faster to solve than the numerical integration method to find the approximate value of a definite integral, i.e., the Trapezoidal Rule. According to them again, the answer obtained from the way of working using the Fundamental Theorem of Calculus is more right against the Trapezoidal Rule. The approximate integral value will undoubtedly be more accurate for large sub-interval values. However, they argue that the drawn sub-intervals are at most eight sub-intervals.

Discussion

Firstly, post-secondary students' understanding of definite integral involves how they communicate with friends who cannot attend class to learn about definite integral. Analysis is based on three categories: mathematical language, skills, and graphics. Table 1 shows two categories, skills and graphics, which are the dominant behaviors in the circle of post-secondary students. Based on the given category, how the students communicate with friends about definite integral certainly involves several features: (i) Communication-based on Mathematical Language, which shows that they deepen the way they think and interact in understanding the definite integral concept. Here, students can think mathematically and generate ideas by providing information from definite integral situations. (ii) Communication is based on Skills that show existing knowledge of students in communicating, including functional operations and integral techniques that focus on solving problems and not on answers only, and (iii) Graphical Communication is based on the graphics that show that they have a strong understanding in imagining to discuss the concept of the definite integral.

Secondly, post-secondary students' understanding of definite integral involves how they communicate with friends who cannot attend class to learn about the area under the curve, which is analyzed based on two categories: communication-based on graphics and skills. Table 2 shows the two categories of behavior dominant among post-secondary students. Based on the category given, how students communicate with a friend about the area below curve graphs involve some specific features: (i) Graphical Communication based on graphics, which shows that they apply a chart style sketch, graphs, diagrams, etc. more effectively in discussing definite integral, and (ii) Communication-based on Skills students' ability to explain effectively in symbolizing notation and represent certain integral symbols with others correctly to ensure that the skills shown are clear and accurate.

Thirdly, post-secondary students' understanding of definite integral involves communicating with friends who cannot attend class to learn how to solve analytic definite integrals based on one category only, which is Communication on Skills. In Table 3, based on the categories given, how students communicate with a friend on how to solve definite integrals involves some specific features, which are skill-based Communication by explaining confidently the Fundamental Theorem of Calculus and choosing the basic properties of definite integrals that can be used use as definite integral work.

Research findings on how post-secondary students communicate with their friends who could not attend the lecture on definite integral indeed showed that students are inclined and able to explain skillfully and visually. This is aligned with recommendations from the Syllabus for Additional Mathematics subjects KSSM (2018) that communication skills mathematically emphasized to students to be able to express concepts and results work by using correct and accurate mathematical terms and sentences in order for students' ability to translate can be improved in situations involving mathematical models and vice versa.

This study also found that students can communicate with their friends about definite integral by finding the area under the curve. However, once again the findings of this study are not consistent with the findings of the study others, namely Rasslan and Tall (2002), Rosken and Rolka (2007), Sealey (2008), Lois and Milevicich (2009), Lawrence (2011), Rubio and Gomez-Chacon (2011), Chih-Hsien (2012), Fergusan (2012), Tuan Salwani and Effandi (2011, 2012), Yuzita, Wester and Steinberg (2012) and Dina and Zolkepeli (2015) found that students experience difficulties using definite integral with concepts in the area under the curve graph. This can be overcome if students deeply understand definite integral, which can be highlighted and explored. In addition, it also helps them solve problems by finding the area under a curve, not to mention using the Trapezoidal Rule to calculate using a scientific calculator (Hasliza & Faridah, 2014).

Conclusions and Implications

From the findings research mentioned above, the researcher found some significant themes through how to relate research results to theory, research, policy, and current practice or past, and extrapolate the results of the study to future practice in fields that are unknown or have never been experienced (Nik Azis, 2014). This theme was created based on the observations of the researcher after discussions with mathematics experts on the findings of this study obtained, agreed, and presented as a contribution to the study to be more meaningful and can benefit the needs of this study, and follow-up studies are carried out.

Table 4: New Themes Based on Research Findings for Communication

Subconstructs of Understanding	**Category**	**New Emergent Theme**
Communication	Mathematical Language Skills Graphical	Argument

The argument is the best theme that results from the findings of a study on how post-secondary students give meaning, create reasoning, and communicate with their friends who cannot be present; learning about definite integral indeed occurs. KSSM (2018) suggests that Arguments can provide thinking and intellectual empowerment when students are guided and trained to make and verify conjectures, provide logical explanations, and analyze, evaluate, and justify everything in math activities. Therefore, the lecturer's task needs to be changed by encouraging students to ask questions and giving opportunities and space for students to interpret mathematical ideas actively (Tillema & Hackenberg, 2011). This student's Argument includes their presentation in explaining the ideas and strategies used in integration orally and non-verbal can be expressed well and the concept. Language usage mathematics, especially correct and informal definite integral, makes it easy to accept the knowledge presented. The result is that behavior and acceptance of knowledge or sharing received by friends with students will be different, and they will easily understand and learn the topic of the definite integral. To create an atmosphere of effective pedagogy, students are given enough space to elaborate statements and present mathematical ideas, whether speaking, listening, writing, reading, drawing, or body movement through questioning techniques suitable for them to argue (Baharom et al., 2009; MoE, 2018). However, the student's ability to communicate with each other needs to be given attention as well so that the presentation about mathematical knowledge can be conveyed in their language.

The results of this study provide three implications for educational practice, post-secondary mathematics curriculum, and further research. Educational practices that need to be refined include teaching and learning about definite integral, applying the theory used in this study in the classroom, and developing an awareness of students' in-depth basic knowledge about definite integral. The Malaysian Ministry of Education, in particular, needs to rethink the mathematics education policy, especially the field of Calculus in Additional Mathematics subjects, which is appropriate to the cause of the decline of students who take calculus subjects so that this subject is no longer considered difficult and tedious at the post-secondary level. Finally, further research can be done on students at the first-degree level in institutions of higher learning, especially in engineering, not only to help students overcome their difficulties on the topic of integrals but also to know how to teach definite integral that works well for students.

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References

Abadi. & Fiangga, S. (2018). Using historical perspective in designing discovery learning on Integral for undergraduate students. *IOP Conference Series: Materials Science and Engineering*. Universitas Negeri Surabaya, Surabaya.

Baharom, M., Ahmad, E., Mohd Yusop, A. H., Jamaluddin, H., & Sarebah, W. (2009). Komunikasi dalam matematik dalam kalangan kanak-kanak. *Persidangan Kebangsaan Pendidikan Sains dan Teknologi*, 1-17.

Chih, H. H. (2012). Engineering students' representational flexibility – the case of the definite integral. *World Transactions on Engineering and Technology Education*, 10(3), 162–167.

Christian, S. D., Elmarie, T. R., and Corazon, P. (2022). Analysis of Difficulties of Students in Learning Calculus. Sci.Int. (Lahore),34(6),1-4.

Dina, S. N, & Zolkepeli, H. (2015). Keberkesanan penggunaan perisian AUTOGRAPH dalam meningkatkan kemahiran komunikasi matematik dan pencapaian pelajar. Master thesis. UKM.

Ferguson, L. J. (2012). Understanding calculus beyond computations: A descriptive study of the parallel meanings and expectations of teachers and users of calculus. (Unpublished PhD thesis). Indiana University, Bloomington, United States.

Ferrer, F. P. (2016). Investigating Students' Learning Difficulties in Integral Calculus. *International Journal of Social Sciences*, 2(1), 310-324. California, USA.

Hasliza, H., & Faridah, I. (2014). Mengenalpasti Kesalahan Lazim Dalam Topik Petua Trapezium dan Simpson. Jabatan Matematik, Sains dan Komputer, Politeknik Tuanku Sultanah Bahiyah. Retrieved from February 4, 2019, from ecrim.ptsb.edu.my/

Jamal, I. N., and Mustafa, N. (2023). The Impact of Visual Communication on Students' Learning Experience Towards Memory Recognition and Enhancement. *Journal of Contemporary Islamic Communication and Media*, 3(1), 179-196. https://jcicom.usim.edu.my/index.php/journal

Jones, S. R. (2010). Applying mathematics to physics and engineering: Symbolic forms of the integral. (Unpublished PhD thesis). University of Maryland, Baltimore.

Kementerian Pendidikan Malaysia. (2018). Dokumen Standard Kurikulum dan Pentaksiran Tingkatan 4 dan 5 KSSM Matematik Tambahan. Kuala Lumpur: Bahagian Pembangunan Kurikulum, Kementerian Pelajaran Malaysia.

Lawrence, B. A. (2011). Constructive Calculus in College Mathematics Unpublished PhD thesis). Columbia University, New York, United States.

Lois, A. & Milevicich, L. (2009). The impact of technological tools in the teaching and learning of integral calculus. *Proceedings of CERME 6* (pg.1060-1069).

Nik Azis, N. P. (1999). Pendekatan konstruktivisme radikal dalam pendidikan matematik. Kuala Lumpur: University of Malaya.

Nik Azis, N. P. (2014). Penghasilan disertasi berkualiti dalam pendidikan matematik. Kuala Lumpur: University of Malaya.

Rasslan, S. & Tall, D. (2002). Definitions and Images for the Definite Integral Concept. In Cockburn, A. & Nardi, E. (Eds.), *Proceedings of the 26th PME*, 4, 89-96.

Rubio, B. S. & Gomez-Chacon, I. Ma. (2011). Challenges with visualization. The concept of integral with undergraduate students. *Proceedings of the Seventh Congress of the European Society for Research in Mathematics Education (CERME-7)*, University of Rzeszow, Poland

Romeo, N. (2020). Pemahaman Pelajar Lepasan Menengah dalam Pengamiran Tentu. *PhD Thesis*. University of Malaya.

Rosken, B. & Rolka, K. (2007). Integrating Intuition: The Role of Concept Image and Concept Definition for Students' Learning of Integral Calculus. *The Montana Mathematics Enthusiast*, Monograph 3, 181-204.

Sealey, V. L. (2008). Calculus students' assimilation of the Riemann integral into a previously established limit structure. (Unpublished PhD thesis). Arizona State University, United States.

Smart, A. (2010, April). A Student's Symbolic and Hesitant Understanding of Introductory Calculus. Dalam Joubert, M. & Andrews, P. (Eds), *Proceedings of the British Congress for Mathematics Education* (h. 215-222). University of Ottawa, Canada.

Syed Uzma, P. B, Imtiaz, A. K., Ajab, A. L., Irfan, A. S., Sadia, B., and Azizullah A. (2023). The Communication Barriers and their Impacts on the Academic Performance of the Graduate Students. *Journal of Positive School Psychology*, 7(5), 605-612. https://journalppw.com/

Tillema, E., & Hackenberg, A. (2011). Developing Systems of Notation as A Trace of Reasoning. For the Learning of Mathematics 31(3), 29-35.

Tuan Salwani, A. & Effandi, Z. (2015). Using Technology in Learning Integral Calculus. *Mediterranean Journal of Social Sciences*, 6(5), 144–148. Universiti Kebangsaan Malaysia, Malaysia.

Tuan Salwani, A. & Effandi, Z. (2012). Module for learning integral calculus with Maple: Lecturers' Views. *The Turkish Online Journal of Educational Technology*, 11(3), 234-245.

Tuan Salwani, A. & Effandi, Z. (2011). Integrating computer algebra systems (CAS) into the university's integral calculus teaching and learning. *International Journal of Academic Research*, 3(3), 397-401.

Von Glasersfeld, E. (1991). Knowing without metaphysics: Aspects of the radical constructivist position. In Steier F. (ed.) *Research and reflexivity*. Sage, London, (pg.12–29).

Von Glasersfeld, E. (1996). Aspects of radical constructivism and its educational recommendations. In L. P. Steffe, P. Nesher, P. Cobb, G. A. Goldin & B. Greer (Eds.), *Theories of Mathematical Learning* (pg.307-314). Hillsdale, NJ.

Yuzita, Y., Wester, M., & Steinberg, S. (2012). Alat bantuan pembelajaran berautomasi untuk kalkulus vektor: Pengamiran terhadap rantau satah. *Jurnal Teknologi Maklumat dan Multimedia Asia-Pasifik*, 1(1), 57-67.

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