# CALCULATOR FOR CRITICAL THINKING IN MATHEMATICS LESSON: EXPERIENCE WITH 4TH GRADE STUDENTS

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There is perception about calculator within school mathematics setting is that it has no purpose aside from computing tool and can have negative impact on the students' mathematics ability, especially in lower educational stage. In Indonesia, using calculator in the classroom is frowned upon and it is prohibited in examination. In this study, we attempted to answer to this issue by investigating the impact of calculators on the students' critical thinking. Through design research, we developed mathematics learning material involving calculator for 4th grade students. The implementation of the learning materials is conducted in nine schools in Yogyakarta. The data is collected in the form of video recording, which is then analyzed according to critical thinking framework. This paper reports the result from the first cycle of this study. The result is expected to contribute to the literature of mathematics education and help rectify the perception on the use of calculator in primary school mathematics.
Keywords: technology, calculator, critical thinking

## Introduction

Ever since calculator reached global calculation in 1970-s, its use in school environment has been met with endless debate. Overwhelming majority of education practitioners, parents, and stakeholders fear that continuous use of calculator will hinder the students' understanding of basic mathematical procedures and their skills acquisition, especially in lower grades (Banks, 2011). There is also concern that the use of calculator will be detrimental on their ability to perform mental computation which result in dependency (Lee, 2006). Calculator is part of technology, yet the all-encompassing term of ICT, which is commonly suggested as a way to make mathematics lessons more innovative and enjoyable, often excludes calculator (Savelsbergh et al., 2016).

The widespread apprehension toward calculators manifest itself in the form of government policies. Many western countries, such as the United States, endorsed calculators use not only in daily lesson, but also during exams (NCTM, 2000). East and Southeast Asian countries are typically stricter when it comes to using calculator in school. In

Indonesia, calculator is banned in national examinations (BNSP, 2020), even though there is no specific policies on its use in everyday classroom activities.

However, the bad reputation suffered by calculator regarding its use in primary school is not supported by research findings. The use of calculator in tandem with pen-and-paper exercise has been found to positively affect their problem solving skills, since calculator lift the burden of computation away and let the students focus on their problem solving strategies (Stacey & Groves, 1994; Wheatley, 1980). The students who use calculators is also reported to possess better attitude toward mathematics compared to those who do not use calculators (Ellington, 2003; Hembree & Dessart, 1986). Its availability and affordability is also viewed in positive light (Kissane & Kemp, 2012).

Considering the favorable findings regarding calculator, it seems plausible that the concern toward its educational use stands on weak ground. Technology in the classroom, including calculators, does not have to make traditional pen-and-paper exercise obsolete; in fact, with the right strategy, it can improve and reinforce it. It is up to the teachers to not see it as something to avoid and instead embrace it as a challenge.

In order to encourage teachers to explore calculator's use in the classroom, further research centered on best practice is needed. One of the topics, which has not been mentioned in calculator research, is critical thinking.

Critical thinking is a very important ability, so important that it is hailed as one of the skills needed to persist in 21st century. It is a complex subject encompassing many characteristic, such as rationality, skepticism, or unbiased analysis. Many definitions exist; one of them is Facione (2011), which defines that critical thinking consist of six core cognitive skills, namely interpretation, analysis, inference, explanation, evaluation, and self-regulation.

This study aims to see whether using calculator in primary school can stimulate the students' critical thinking. The research question we attempt to answer through this study is *how does the use of calculator support 4th grade students critical thinking in mathematics classroom?*

## Methods

This study is part of a four-cycle design research aimed to design learning materials incorporating calculators for primary school mathematics. Design research is an approach whose purpose is to develop theories about the process of learning and designing the means that support that learning (Gravemeijer & Cobb, 2006), which we consider suitable for the aim of this study.

Design research consist of three phases namely design, teaching experiment, and retrospective analysis (Eerde, 2013), as depicted in Figure 1.

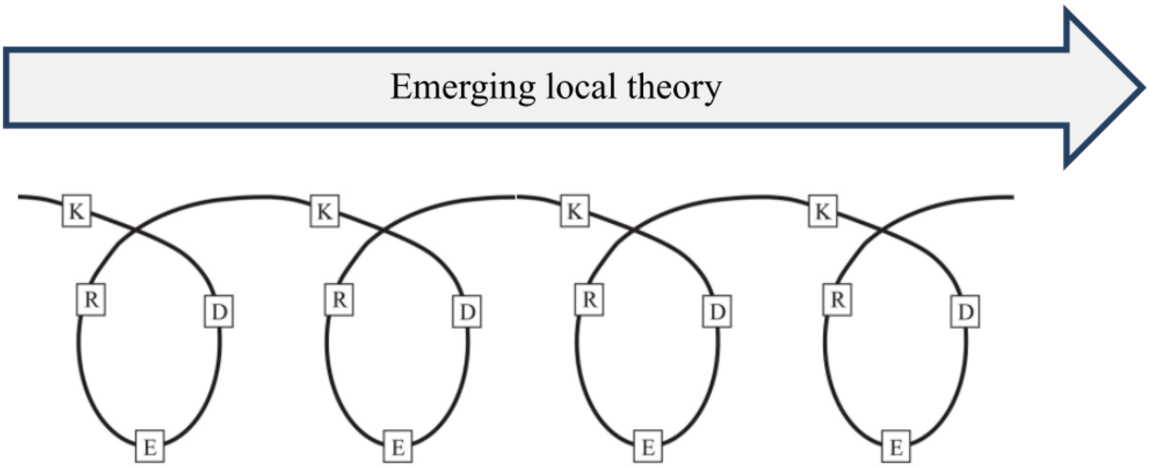


**Figure 1** Phases of Design Research

Based on the current knowledge (K), which comprises literature review, curriculum documents, and school textbook, the researcher design (D) learning activities. This is the Design phase. In the Teaching Experiment phase, the activities are put into practice in teaching experiment (E). In the Retrospective Analysis phase (R), the researcher reflect on the result of teaching experiment, which contribute to new knowledge. The new knowledge then starts a new cycle. This study consists of four cycles; this article presents the initial analysis from the first cycle.

***Designing classroom activities***

To refute the stereotype that calculator merely serves as computing tools, Ruthven (2003) and Kissane (2017) proposed four ways calculator can be used in the classroom that emphasis its educational purpose, namely:

1. *computation implementation* or *calculation*, which is using calculator to perform computation otherwise impossible to perform manually by hand,
2. *result checking* or *affirmation*, indicating the use of calculator to confirm prediction or assess estimation,
3. *trial improving* or *exploration*, implying calculator as a means for students to explore several possibilities and derive conclusions, and
4. *structure modelling* or *representation*, which is using calculator to demonstrate numerical structure or concept.

Therefore, when designing the activities, we made sure to focus on these four strategies and minimize the use of calculator simply as computing device. The example of the activities, which are in the topic of fraction representation (namely representing regular fraction as mixed fraction and vice versa), are depicted in Figure 2. There are two parts in this worksheet; the second part more or less follow the same structure and poses similar questions, but the problems uses different numbers.

The activities are designed for 4$^{th}$ grade students. According to Indonesian national curriculum, the students in 4$^{th}$ grade already possesses knowledge on division as arithmetic operation and fraction which is introduced in previous grades. However, the concept of fraction introduced in the 3rd grades is part-whole relationship, therefore prior to the teaching experiment, the teacher introduced the students to the concept of fraction as division.

To bridge the students' prior understanding on regular fraction to the learning objectives which is mixed fraction, we start the worksheet with division problems (question 1). The context introduced is about building solar panels from solar cells, in which the students have to guess by themselves the mathematics operation needed to solve the problem. This problem concludes in division with remainder, and when represented as fraction, results in larger numerator than denominator. By the end of question 1, the students are conjectured to already identify the result and the remainder of the division.

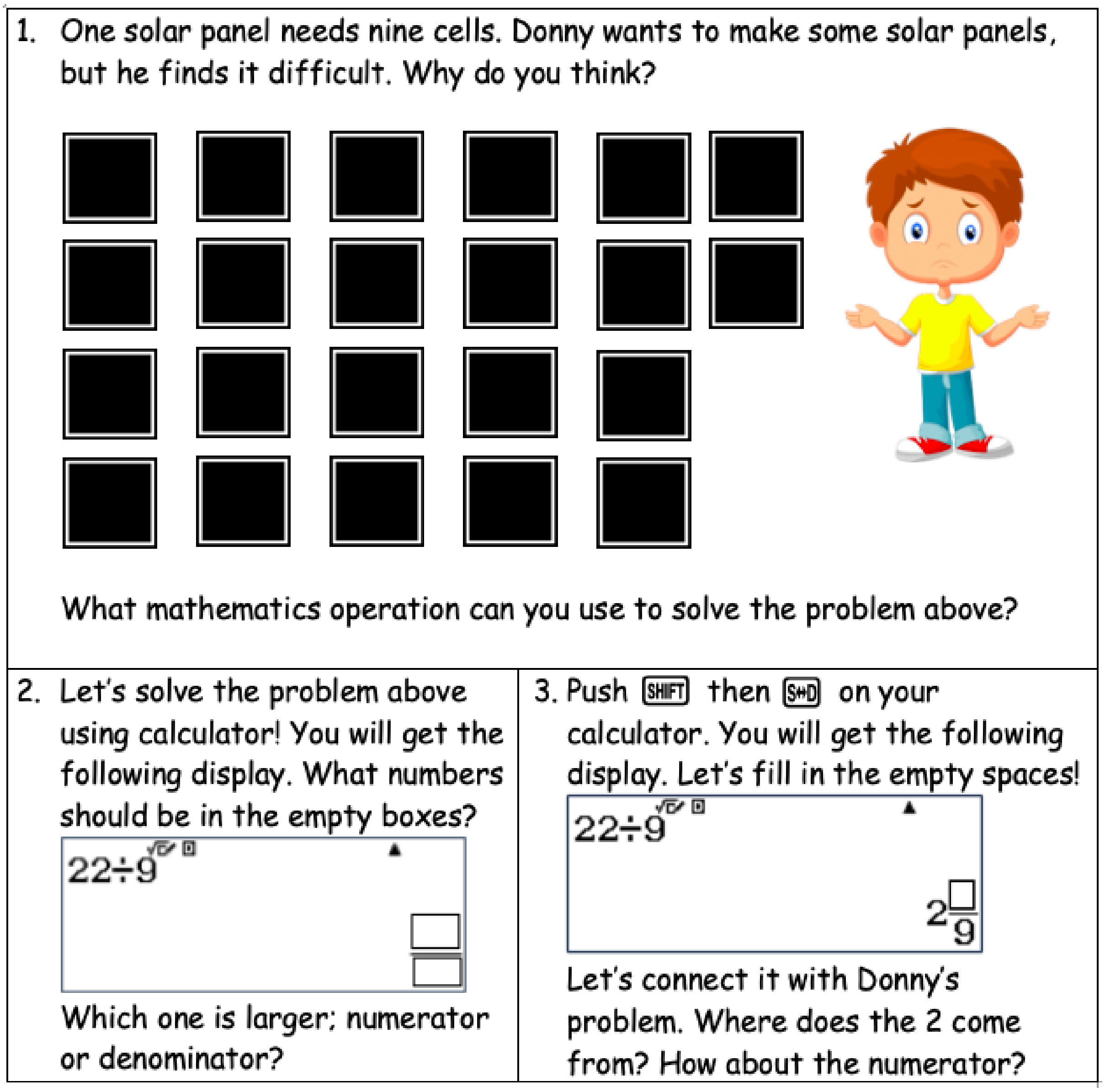


**Figure 2** Example of calculator-enhanced activities in the topic of fraction representation

In Question 2, the students are asked to solve the problem with calculator. However, prior to pressing the button, they have to guess first. We predict that the students will guess with the result and the remainder they counted in Question 1, hence the conjecture is that they will be surprised upon discovering that the calculator displays fraction. The teacher can use connect this moment to their prior understanding on fraction as division. In Question 3, the students are asked to press q then n button, resulting in the regular fraction changing to mixed fraction.

In this part of the problem, the students use calculator for its *structure modelling* or *representation* purpose. By demonstrating how regular fraction changes into mixed fraction, and relating it to the result of division, the students are expected to make a connection between the result of the division and the components of mixed fraction. Through several of these examples, the students then derive a conclusion on what a mixed fraction is and how to represent regular fraction as mixed fraction.

The problem used in this study is contextual and open-ended problems which encourage critical thinking because it requires students to ask questions, analyse situation, and decide the right knowledge to apply to solve problems (Bruning, 2005). Throughout the worksheet, we incorporate many fill-in exercises to make it more interactive for the students. The students are also encouraged to use calculators with written exercise, because similar to their teacher, the students are also very cautious about using calculators in the classroom.

### *Research setting*

Prior to the research, all the participating teachers were enrolled in four-day workshop on utilizing calculators for primary mathematics teaching and learning. The purpose of this workshop is, aside from supporting the teachers with technical knowledge about calculator, is also to introduce how it can be used in educational setting and to socialize the worksheet and lesson plan. The teachers also installed calculator emulator in their personal computer, to make it easier in displaying calculator interface to the entire class.

This study was conducted in a primary school in Yogyakarta. Twenty 4$^{th}$ grade students participated in the first cycle. Most come from middle to lower socio-economic class and are familiar with calculators, yet its use is prohibited in school. The teacher who normally teach the class, taught the lesson. During the lesson, the students were split into groups of four.

### *Data Collection and Analysis*

We collected the data in the form of video recording of the classroom discussion. Three cameras, one static and two moving around the classroom, are used to capture the classroom interaction. Not all interactions were recorded, however, since the decision on what and how to capture is somewhat influenced by the research question. Therefore, the cameras moved around the classroom capturing any group that visibly had productive discussion, which means the video recordings are not continuous and chronological documentation of the whole lesson. Instead, it comprises snippets of discussion and group work that potentially gives meaningful information to answer the research question.

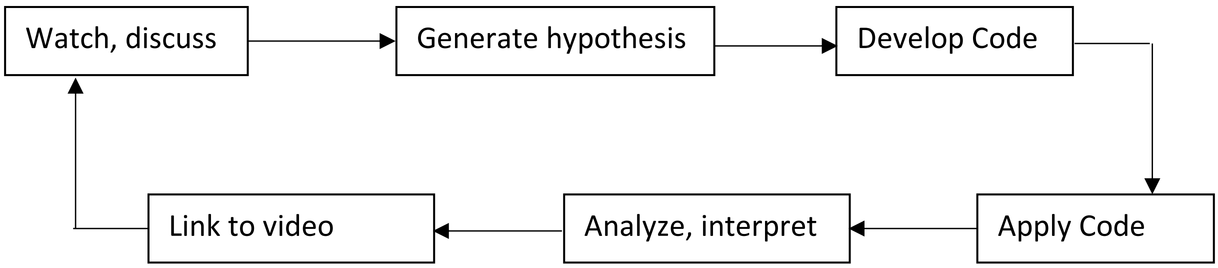


**Figure 3** Cycle of coding and analysis of video data (Jacobs et al., 1999)

To analyze the data, we followed cyclical process of coding and analysis developed by Jacobs, Kawanaka, and Stigler (1999) as depicted in Figure 3. First, the team of researchers watch and discuss the video to acquire the overall result of the teaching experiment and formulate hypothesis. Next, the researcher develop code based on the critical thinking framework proposed by Facione (2011). Codes are tags or labels used to assign meaning to data collected during the study, to ensure the objectivity and the reliability of the qualitative data analysis (DeCuir-Gunby, Marshall, & McCulloch, 2011; Jacobs et al., 1999). Codes are not meant to stay fixed; they will be constantly revised during the data analysis. While no prior research have used Facione's framework to develop video data analysis codes, we argue that the framework is general enough to apply for any population and age group, including 4$^{th}$ grade students.

The initial version of the code developed for this study is as follows.

**Table 1** Codes for critical thinking

| **Code** | **Meaning** | **Description** |
|---|---|---|
| I1 | Interpretation | Comprehending and expressing the students' own understanding of the problem |
| I2 | Inference | To identify and secure elements needed to draw reasonable conclusion; to form conjectures and hypothesis |
| A | Analysis | To identify the intended and actual inferential relationship in the problem, either among statements or information; making connection |
| E1 | Evaluation | Judging and assessing information available in the problem. |
| E2 | Explanation | Explaining the results of one's reasoning |
| S | Self-regulation | Related to metacognition, self-consciously monitoring, assessing, and evaluating one's learning |

The following step is applying the code to the video data. The researcher watches the video and assigning a code to unit of analysis, namely an instance of the students' verbal or non-verbal response to the instruction, that is identified throughout the lesson. This instance can be in the form of the students' answering the teacher's question, students discussing with their peers, or the written work of the students.

The result is compiled and analyzed to investigate to derive conclusion in regard to the research question. The conclusion is further compared to the video, which start the cycle all over again. Relevant section is chosen and transcribed to support the conclusion.

## Results and Conclusion

While research involving video data usually transcript the video to be followed by analyzing the transcript, due to time constraint, transcribing the whole video is deemed impractical for this study. Therefore, the code is applied to the video itself, with timestamp linking the code to the intended vignettes of the video.

The result suggest that the majority of instances related to critical thinking in the video recording fall under Interpretation (I1) and Analysis (A). Minimal evidence on Explanation (E2) was available, as the students had a hard time formulating their thoughts, either in written or spoken words. On the other hand, no evidence is identified on Evaluation (E1), Inference (I2), and Self-regulation (S). The evidence are not universally recorded among the students; some students responded more actively to the teacher's instruction and have more productive discussion than others.

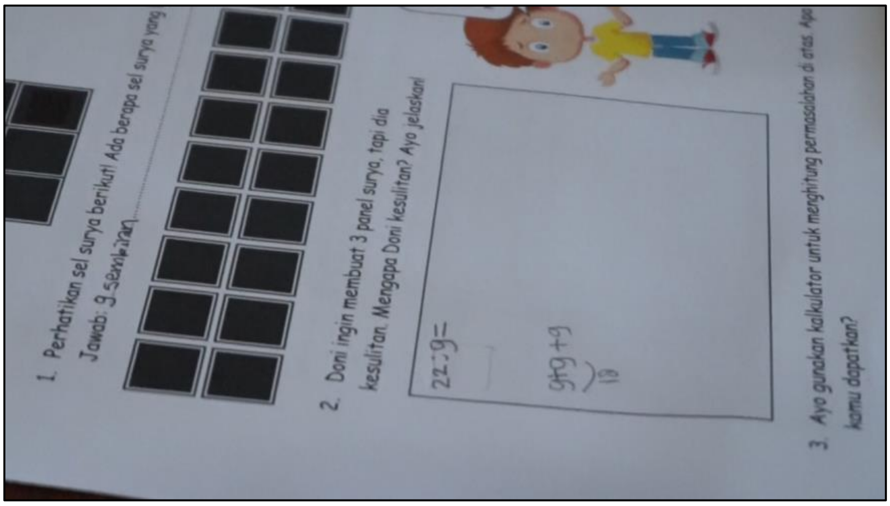


**Figure 4** The repeated addition the students did in an attempt to understand the problem.

Interpretation is identified the most frequently during question 1; both in first and second part of worksheet. The students used different strategies in attempting to understand the difficulties faced by Donny. One of the strategies are repeated addition (Figure 4), in which the students add the divisor repeatedly. The student in above picture added the divisor two times before stopping and realize what the "difficulty" is. Other strategy that appears is grouping the object, in this case the solar cell, either by drawing or hand (Figure 5).

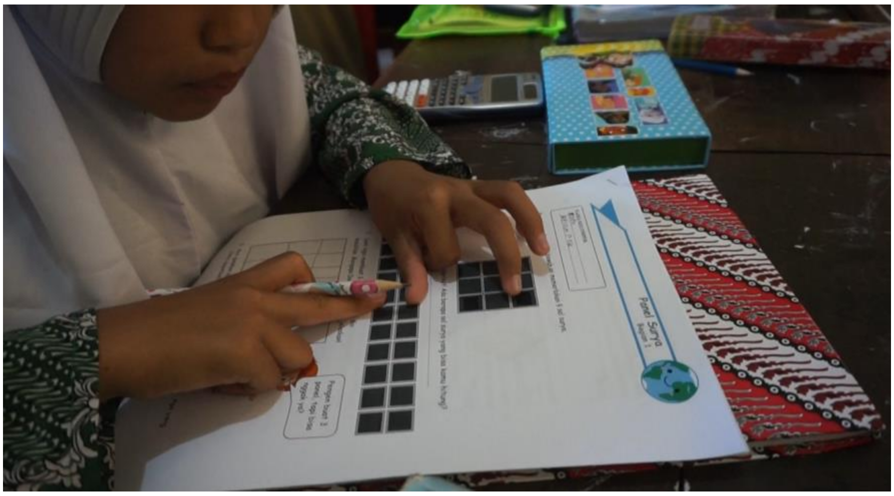

**Figure 5** The student group the objects by hand

While almost all students could arrive to conclusion that the difficulties faced by Donny is because there are not enough cells to make whole panels, only a few students can interpret that division is the mathematics operation needed to solve the problems.

On the other hand, Analysis is identified mostly in Question 3. Initially, the students are having difficulty identifying the previously unknown mixed fraction, with some students only mention the fraction part. The following excerpt (Fragment 1) depicts whole-class discussion on this question.

**Fragment 1**

1 Teacher : .. now the number on the screen is 22/9. What number is this?

2 Students : Fraction!

3 Teacher : Now we are going to learn using his calculator. Let's push the q button – this one – and then n. If we push enter, what do you think we are going to get?

4 Students : [inaudible]

5 Teacher : let's try, shall we? One, two, three … what do we get?

6 Student A : Four-over-nine?

7 Student B : Four-over-nine!

8 Teacher : Really? Come on, how should we read it?

9 Student C : There is a four … four over …

10 Student D : Two, four-over-nine?

11 Teacher : How should we read it? Two …

12 Student B : … four-over-nine!

13 Teacher : That's correct, we should read it two four-over-nine. But why two? How does it connect to your previous calculation? Two four-over-nine, how come?

14 Student B : The two comes from there [pointing to the board] the division

15 Teacher : This one?

16 Student B : and the four comes from the remainder. And the nine is the divisor
17 Teacher : that is correct!

There is evidence that by connecting the calculator display to the result of division calculated previously, some students are able to conclude that the whole number denotes the result of division, while the numerator denotes the remainder.

## Discussion

In this section, we will discuss how the design of activities contribute to the findings regarding cognitive skills related to critical thinking found in the video. According to the result discussed in previous section, it was evident that the cognitive skills related to critical thinking that occurred with the use of calculator is Analysis. Other cognitive skills that implies critical thinking emerged too, such as Interpretation, however it mostly coincided with non-calculator question.

There are some explanations that might shed light on this phenomenon. Critical thinking is learnable, even with young children. Open-ended problems that does not provide any clues about mathematics concept needed to solve it are often cited as beneficial for higher order thinking skills or HOTS (Fong, 2000), however associating activities are also suggested strategies to develop critical thinking of young learners (Rahman, 2014). In Question 2, where the students use calculator as means of representation, the calculator itself support the students to make a connection between the result of division and the representation of mixed fraction. Therefore, the use of calculator in primary school can support the students' critical thinking, specifically analysis skills, through its *Structure Modelling* or *Representation* purpose.

We suggest future research to venture into other purposes of calculators and other cognitive skills in critical thinking, as well as the connection between the two. The use of calculator in primary school mathematics is still an interesting idea which is rarely explored, hence it is still potential for future researcher. However, we also suggest future researchers to explore other mathematics content.

Lastly, this study is not without limits. We acknowledge the small sample and the limited timeframe as the main drawbacks of this study. Future researchers are encouraged to conduct longer studies with larger sample.

## References

Banks, S. (2011). A Historical Analysis of Attitudes Toward the Use of Calculators in Junior High and High School Math Classrooms in the United States Since 1975 (Cedarville University). https://doi.org/10.15385/tmed.2011.1

Bruning, K. (2005). The role of critical thinking in the online learning environment. *International Journal of Instructional Technology and Distance Learning*, *2*(5), 21–31. Retrieved from http://itdl.org/journal/may_05/article03.htm

DeCuir-Gunby, J. T., Marshall, P. L., & McCulloch, A. W. (2011). Developing and using a codebook for the analysis of interview data: An example from a professional development research project. *Field Methods*, *23*(2), 136–155. https://doi.org/10.1177/1525822X10388468

Eerde, H. (2013). Design research: Looking into the heart of mathematics education. *Proceeding The First South East Asia Design/ …*, 1–11. Retrieved from http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Design+research:+looking+into+the+heart+of+mathematics+education#0

Ellington, A. J. (2003). A Meta-Analysis of the Effects of Calculators on Students' Achievement and Attitude Levels in Precollege Mathematics Classes. *Journal for Research in Mathematics Education*, *34*(5), 433. https://doi.org/10.2307/30034795

Facione, P. a. (2011). Critical Thinking : What It Is and Why It Counts. *The California Academic Press*, *1*(1), 1–28. Retrieved from https://www.insightassessment.com/CT-Resources/Teaching-For-and-About-Critical-Thinking/Critical-Thinking-What-It-Is-and-Why-It-Counts/Critical-Thinking-What-It-Is-and-Why-It-Counts-PDF

Fong, Pui Yee. (2000). Open-ended problems for higher-order thinking in mathematics. *Teaching and Learning.20(2). 49-57*

Gravemeijer, K., & Cobb, P. (2006). Design research from a learning design perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational Design Research*. https://doi.org/10.1007/978-1-4614-3185-5_11

Hembree, R., & Dessart, D. J. (1986). Effects of Hand-Held Calculators in Precollege Mathematics Education : A Meta-Analysis. *Journal for Research in Mathematics Education*, *17*(2), 83–99.

Jacobs, J. K., Kawanaka, T., & Stigler, J. W. (1999). Integrating qualitative and quantitative approaches to the analysis of video data on classroom teaching. *International Journal of Educational Research*, *31*(8), 717–724. https://doi.org/10.1016/S0883-0355(99)00036-1

Kissane, B. (2017). Learning with Calculators: Doing More with Less. *Australian Mathematics Teacher*, *73*(1), 3–11. Retrieved from http://www.aamt.edu.au/Webshop/Entire-catalogue/Australian-Mathematics-Teacher

Kissane, B., & Kemp, M. (2012). The Place of Calculators in Mathematics Education in Developing Countries. *Journal of Science and Mathematics Education in Southeast Asia*, *35*(2), 102–118.

Lee, K. P. (2006). Calculator Use in Primary School Mathematics : A Singapore Perspective. *The Mathematics Educator*, *9*(2), 97–111.

NCTM. (2000). *Principles and Standards for School Mathematics*. Virginia: NCTM.

Rahman, A.A. (2014). Ideas for Developing Critical Thinking at Primary School Level. *Paper presented at an International Seminar on Addressing Higher Order Thinking: Critical Thinking Issues in Primary Education*. Islamic University of Muhammadiyah, Makasar.

Ruthven, K. (2003). Creating a calculator-aware number curriculum. *Canadian Journal of*

*Science, Mathematics and Technology Education*, *3*(4), 437–450. https://doi.org/10.1080/14926150309556581

Savelsbergh, E. R., Prins, G. T., Rietbergen, C., Fechner, S., Vaessen, B. E., Draijer, J. M., & Bakker, A. (2016). Effects of innovative science and mathematics teaching on student attitudes and achievement: A meta-analytic study. *Educational Research Review*, *19*, 158–172. https://doi.org/10.1016/j.edurev.2016.07.003

Stacey, K., & Groves, S. (1994). Calculators in Primary Mathematics. *72nd Annual Meeting of the National Council of Teachers of Mathematics*.

Wheatley, C. L. (1980). Calculator Use and Problem-Solving Performance. *Journal for Research in Mathematics Education*, *11*(5), 323–334.