Our Prospective Mathematic Teachers Are Not Critical Thinkers Yet

by Ali Mahmudi

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OUR PROSPECTIVE MATHEMATIC TEACHERS ARE NOT CRITICAL THINKERS YET

Abdur Rahman As'ari[1], Ali Mahmudi[2], Elah Nuerlaelah[3]

[1]Universitas Negeri Malang, Jl. Semarang No. 5, Malang 65145
[2]Universitas Negeri Yogyakarta, Jl. Colombo No.1, Yogyakarta, 55281
[3]Universitas Pendidikan Indonesia, Jl. Setiabudi No. 229, Bandung, 40154
Email: abdur.rahman.fmipa@um.ac.id

Abstract

In order to help students develop their critical thinking skills, teachers need to model the critical thinking skills and dispositions in front of their students. Unfortunately, very rare studies investigating prospective teachers' readiness in critical thinking dispositions are available in the field of mathematics education. This study was intended to investigate the level of critical thinking disposition of prospective mathematics teachers. Using vase study methods, three studies were done in Malang.Three levels of critical thinkers were identified from these case studies namely: non-critical thinker, emergent critical thinker, developing critical thinker. Majority of prospective mathematics teachers' critical thinking dispositions are at the non-critical thinker level. Only a few of them are at the emergent critical thinker, and very rare at the developing critical thinker level. It can be concluded that prospective mathematics teachers are not critical thinker yet. Teacher education institutions need to reform their curriculum and instructional practices to improve their students critical thinking skills and dispositions.

Keywords: Critical Thinking, Disposition, Mathematics, Prospective Teachers

Abstrak

Dalam rangka membantu siswa mengembangkan kemampuan berpikir kritis, para guru perlu memodelkan kemampuan dan disposisi berpikir kritis tersebut di hadapan siswanya. Akan tetapi, sedikit peneliti yang menyeliidi tingkat kemampuan berpikir kritis calon guru matematika. Penelitian ini dimaksudkan untuk menyelidiki tingkat kemampuan berpikir kritis calon guru matematika. Menggunakan metode studi kasus, tiga studi kasus telah dilaksanakan di Malang.Tiga tingkat kemampuan berpikir kritis teridentifikasi dari studi kasus ini, yaitu: non-critical thinker, emergent critical thinker, dan developing critical thinker. Mayoritas calon guru matematika masih berada di tingkat non-critical thniker.Hanya sebagian kecil yang berada pada level emerging critical thinker, dan sangat jarang yang berada pada level developing critical thinker. Dapat disimpulkan bahwa calon guru matematika masih belum merupakan pemikir kritis. Lembaga pendidikan guru perlu mereformasi kurikulum dan praktik pembelajaran mereka untuk meningkatkan kemampuan dan disposisi berpikir kritis siswanya.

Kata kunci: Berpikir Kritis, Matematika, Calon Guru

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Critical thinking is a very important topic in modern education. It is required for continuing study at higher levels and to live peacefully (As'ari, 2014), to helps people to make a better and more informed decision (Cottrell, 2005), and to enable people to ensure that they have justifications to believe or do things they are persuaded to do (Bowell & Kemp, 2002). In fact, capacity for critical thinking has been identified as an indicator of how well an individual will perform at school and on the job (Starkey, 2004).

Being a critical thinker is one of the goals of the education system in Indonesia (Depdiknas, 2003). Indonesian critical thinkers who always question, analyze, and criticize arguments presented to

them (Klimoviene, Urboniene, & Barzdziukiene, 2006), are expected to become leaders in Indonesia's future development. Unfortunately, the facts indicate that Indonesian students' ability to think critically is disappointing (OECD, 2014; The Education Quality and Accountability Office, 2013). Therefore, there is an emergency call for educators to find a better way to help Indonesian students to become better critical thinkers.

The focus of mathematics learning, nowadays, which require more on conceptual understanding and the ability to provide justification than just applying mathematicsl rules (Devlin, 2012), indicates that mathematics has a potential role for thinking development, including critical thinking. Therefore, mathematics teachers play a very important role in this work. Mathematics teachers have the potentials to help their students to develop their critical thinking skills and dispositions, and there are four possible ways to teach critical thinking, namely: *general*, *infusion*, *immersion*, and *mixed* (Abrami, Bernard, Borokhovski, Wade, Surkes, Tamim & Zhang, 2008). Mathematics teachers may choose any of these approach. However, the most important thing is that the teacher should be able to model themselves as critical thinker to enable their students having the chances to see, evaluate, imitate, and even develop their own critical thinking dispositions.

Changing the existing teachers' mindset and behavior to become critical thinkers is not an easy task. They are already mature and difficult to change. In addition, preparing prospective teachers is much more strategic, in the long run, than training the existing teachers (Prahmana, Zulkardi, & Hartono, 2012). Therefore, preparing prospective teachers to become critical thinkers is better choice.

Up to now, very limited information is available regarding the prospective mathematics teachers' critical thinking dispositions. Existing studies related to critical thinking dispositions, in the field of mathematics education do not provide a clear profile of prospective mathematics teachers critical thinking dispositions. Studies conducted so far are mostly about the impact of an instructional method toward the improvement or identifying the factors of critical thinking skills (Kurniati, Kusumah, Sabandar & Herman, 2015; Masarigan & Espinosa, 2014; Palinuspalsa, 2013; Mahapoonyanont, 2012; Karim, 2011; Rohaeti, 2010; Mulyana, 2009; Setyaningsih, 2009; Herman, 2007; Myers & Dyer, 2006).

Although Rasiman (2015), actually has investigated the leveling of students critical thinkers. He used closed ended problems as his tool to investigate students' critical thinking dispositions. He did not include other types of mathematical problems, such as: *implicit open ended problems*, *illogical problems*, *incomplete information problems* which could lead to a different challenge for the students. The authors believe that different type of problems will require different dispositions. Hence, there is still a need to investigate the profile of prospective mathematics teachers in Indonesia related to their critical thinking dispositions. Therefore, for the sake of that inquiry, the problem of this study is to what extent is the critical thinking dispositions stage of prospective mathematics teachers in Indonesia?

The result of this study will provide a very important input for designing better teacher education program, especially for prospective mathematics teacher. The result of this study will allow mathematics teacher educators to design curriculum, courses and/or instructional practices that will

improve critical thinking dispositions stage of prospective mathematics teachers, which in the long run will help Indonesian students to become better critical thinkers.

METHOD

The authors define critical thinking disposition dispositions as a tendency to do something, whenever critical thinkers is given certain conditions. Therefore, students' spontaneous responds toward any problem or task, and follow up reflective questions were used as a tool to determine students' critical thinker stage. This is supported by Ng Connie (2006) who stated that observation and interview can be used as ways to measure critical thinking dispositions.

In the first case study, 20 undergraduate prospective mathematics teachers were involved in this study. They were already at the end semester of their 3rd year at undergraduate level. They have taken almost all the mathematics and mathematics education courses except teaching practice and writing an undergraduate thesis. The authors invited them to participate in the study and they were given the following incomplete task as the instrument for this study:

"Prove that if $f(x) = \sqrt{x}$ and $g(x) = x^2$, then $fog = gof$."

(note: *this problem is intended as an incomplete mathematical problem*)

Through an observation (another instrument for this study), the author recorded their response one by one. Later on, the authors conducted interviews to investigate their potentials.

In the second case study, only one master degree postgraduate student was involved in the study. She was at my office to ask my permission for her thesis examination. The authors asked her to solve the following an inappropriate problem. The authors watched and observed what she did during the problem solving activities.

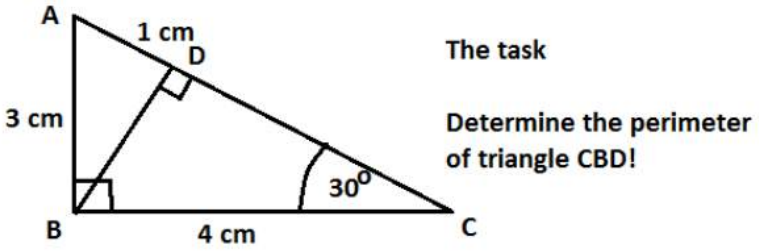

Figure 1. The problem given to one of post graduate prospective mathematics teacher.
(Note: *this problem is intended as an illogical problem*)

The third case study, another 16 master degree postgraduate students were involved in the study. They were at the second semester of the first year of their study at master degree mathematics education program. The author asked them to solve the following incomplete problem.

$$Determine\ the\ solution\ set\ of\ quadratic\ equation\ x^2 = 1.$$

(Note: *this problem is intended as an implicit open ended problem*)

The author watched and observed their works during their problem solving processes, and followed by interviews to see their potentials.

RESULTS AND DISCUSSION

First Case Study.

In the first case study, the students were given the following task:

Given that $f(x) = \sqrt{x}; g(x) = x^2$. Prove that $gof = fog$!

Study indicated 19 (nineteen) undergraduate students directly performed the task and did not show the indicators that they are critical thinkers. They just performed the task mechanically and the following are two of their answers. One of their work is of the following.

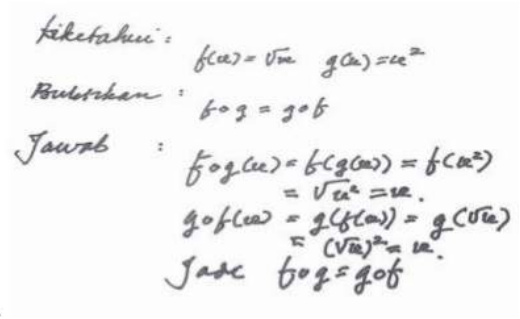

Figure 2. Answer of an undergraduate student

Actually, there is no information available related to the domains of each functions. He did not check to what domain each the composite functions are definable. They just follow the procedural things to show its equality. Another student was even worse and executed the task as the following.

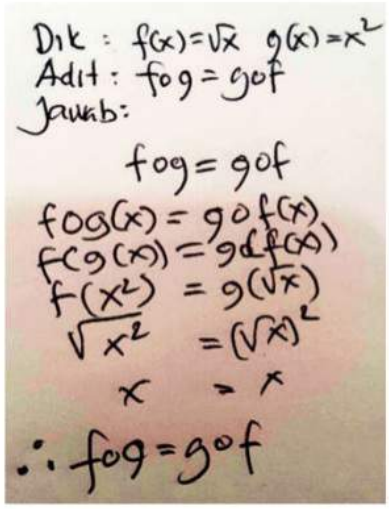

Figure 3. Answer of another undergraduate student

This student used what should be proved as something given. He did not understand the principles of proving. He did not know what should be used as premise(s) and what should to be proven.

Several experts have described several characteristics of critical thinkers. According to Facione (1990), related to life and living in general, critical thinkers are: (1) inquisitive, (2) try to always be well-informed, (3) ready to always use critical thinking, (4) trust to reasonableness, (5) self-confidence, (6) open-minded, (7) flexible, (8) undertand other opinion, (9) objective or fair minded, (10) wise, and (11) ready to change their mind if needed. Critical thinkers are also: (1) maintain clarity, (2) work systematically, (3) perseverence in looking for appropriate information, (4) reasonable, (5) accurate (6) never give up, and(7) try to be accurate as permitted. Similarly, Ennis (2011) stated that critical thinkers: (1) always seeking alternative hypotheses, explanations, conclusions, plans, sources, etc, and be open to them, (2) consider seriously other points of view, (3) try to always be well informed, (4) always endorse a position to the extend that it is justified by the information that is available, and (5) always use their ctitical thinking abilities.

Lai (2011), who conducted a study of literature related to critical thinking. enlisted several critical thinking dispositions expressed by critical thinkers, that are: (1) open mindedness, (2) fair mindedness, (3) the propensity to seek reason, (4) inquisitiveness, (5) the desire to be well-informed, (6) flexibility, respect for, and willingness to entertain, others' viewpoints. This is in line with Kokdemir' thesis (Emir, 2013), who claims that critical thinkers tend express the following attitudes: (1) truth seeking, (2) open-mindedness, (3) analyticity, (4) systematicity, (5) self-confidence, (6) inquisitiveness, maturity.

Based on those characteristics, most of these students cannot be characterized as critical thinkers. However, there are several levels of critical thinkers. According to Paul & Elder (2008), there are six stages of critical thinker development, namely: (1) unreflective thinker, (2) challenged thinker, (3) beginning thinker, (4) practicing thinker, (5) advanced thinker, and (6) master thinker. Students are categorized as an unreflective thinker if they are unaware of significant problems in their thinking. Students are categorized as challenged thinker if they are faced with significant problems in their thinking; as a beginning thinker if they try to improve but without regular practice; as practicing thinker if they recognize the need for regular practice; as advanced thinker if they advance in keeping with their practice. Finally, students are categorized as a master thinker if good habits of thought become a second nature to them. Based on this classification, they are not master thinkers, and they may be at the lower level. A more in depth investigation is then required to classify these students' critical thinker level.

Classifying into six stages, according to the authors, is very demanding. In this preliminary study, authors need to simplify these stages into four classifications only, namely: (1) *non-critical thinker*, (2) *emergent critical thinker*, (3) *developing critical thinker*, and (4) *mastering critical thinker*. Students are categorized as *non-critical thinker* if they are unaware that they need to behave critically to things they need to do or belief. Students are categorized as *emergent thinker* if they express the need to behave critically, having challenged by question of their responds; as *developing critical thinker* if they always recognize that they need to respond critically to any input provided to them, although the responses are

incomplete or inaccurate; as *mastering critical thinker* if they always present their critical thinking skills appropriately to produce the best responses to things that they need to do or believe.

Questioning is considered as a good way to improve critical thinking (Browne & Keely 2007). This idea challenged the authors to use questioning strategies to identify the highest level possible of their critical thinker level. Therefore, in this study, having written their work, the authors interviewed them and provided several reflective questions such as:

(1) *Are you sure with your answer*?

(2) *Why do you think that your respond is appropriate*?

(3) *Do you think that we have to prove if there is a command "prove that"*?

(4) *Don't you see any weaknesses of the task*?

The first question was intended to check their confidence of their work. Second question was intended to investigate the reasons they have related to their confidence. The third question was intended to see whether they have to follow every command, even from the teacher, or not. The last question was intended to provide a clue for them to use their critical thinking skills to see the appropriateness of the command.

Having interviewed, 12 (twelve) students out of the 19 (nineteen) insisted that there was nothing wrong with their answer. They was unable to use their reasoning skills to see the weaknesses of the task. They just followed the habit of doing proceducal things. The rest 7 (seven) students finally realized that the ranges of the fog and gof could be not equal, which imply that the fog and gof could be not equal functions. They realized that concluding the equation of fog and gof is inaccurate.

In this study, there was 1 (one) student who did not follow the instruction. He realized the weaknesses of the task, but he could not able to revise it to make it correct. He just said that since the domains of both functions were not defined clearly, the two functions cannot be the same. But, he was unable to use his inferential skills that the largest domain of f is the set of non negative real numbers, and the largest domain of g. Hence, the largest domain of gof is the set of non-negative real numbers and the largest domain of fog is the set of real numbers. Since, there are two conditions of two functions to be the same, namely its domain and its rule, the two functions fog and gof cannot be equal functions. This student can be classified as at *developing critical thinker stage*.

So, from the first case study, based on the leveling proposed by the authors above, it can be concluded that there are 12 at the *non-critical thinkers stage*, 7 are at the *emergent critical thinkers stage*, and 1 is at *developing critical thinker stage*. None of them are at *mastering critical thinker stage*.

From the second case study, firstly she (the student) drew the following figure on white board.

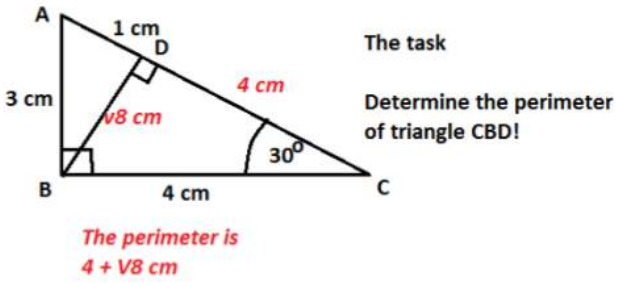

Figure 4. Answer of post graduate Student

But, several minutes later, she stared to the picture she made, and finally she said "*hmmm... seems impossible sir*"
The author then asked: *why*?
The student: *The triangle BCD is a right angled triangle, but the length of BC is equal to the length of BD.*
The author once again asked her: *so.. what is your conclusion?*
The student: *I think the information provided in the problem are wrong. No need to proceed.*

This student immediately just executed the task. She tried to use several mathematical rules to answer the problem. But, whenever she got a specific figure (i,e, BC = BD), she felt that this should be impossible. She remembered a principle that the hypothenuse of a right-angled triangle must longer than the other two sides. She felt that there is something incorrect with the problem.

This student firsly tried to solve the problem (with no effort to comprehensively analyze the information provided in the problem), and when she confronted with something controversial, she tried to think in little bit deeper and identified the inaccuracy of the information provided in the problem. She did not start from the very beginning to think critically. Therefore, based on the leveling proposed by the authors above, it can be concluded that this student is at the *emergent critical thinker* level and approaching to the *developing critical thinker*.

From the third case study, all of the 16 students showed that {-1.1} as the solution set. They just follow the assumption that if there is no explicit explanation about its universe, then the universal set of the problem has to be the set of all real numbers R.

When the author showed them alternative solutions, namely:

$$\{1\}, if\ x \in N, N\ is\ the\ set\ of\ natural\ numbers,$$
$$\{-1\}, if\ x \in Z^-, Z^-\ is\ the\ set\ of\ all\ negative\ integers,$$
$$\emptyset, if\ x \in P, P\ is\ the\ set\ of\ all\ prime\ numbers,$$

87.5% or 14 out of 16 students did not agree to these alternative. They still insisted that they have to follow the convention that *if there is no explicit universal set applied to any variable, the universal set should be R, the set of all real numbers*. They don't try to adapt different point of view and come up with several possible solution sets. They keep said that {-1,1} as its solution set only. So, based on the

leveling of critical thinker proposed by the authors above it can be concluded that most of them are at the *non-critical thinker level*, and only a few of them are at *emergent critical thinker*.

Based on these three case studies, it can be seen that prospective mathematics teachers, whether at undergraduate or master degree level, are at the *non-critical thinker level*. Only a few of them are at *emergent critical thinker level*, and very rare are at *developing critical thinker*. None of them are at *mastering critical thinker level*.

This simple study revealed a fact that most of Indonesian prospective mathematics teachers, whether they are at undergraduate or at postgraduate level, are at the *non-critical thinker level*, and they can move up to *emergent critical thinker stage* only when they are given additional time to reflect on their thinking. Considering the seven critical thinking disposition dimensions suggested by Broadbear, Jin, & Bierme (2005), the author categorizes most of these students as *underdeveloped thinkers*. Frequent and voluntary habits of critical thinking defined by Da Ros-Voseles & Fowler-Haughey (2007) were not in existence. This research finding in line with the Biber, Tuna, Incikabi, & Kasmanonu (2013) who reported that mathematics teacher candidates generally possessed low critical thinking dispositions.

One among the reasons of this low level critical thinking disposition is the routine mathematics instruction conducted by mathematics teachers in the classroom. Yuwono (2006) stated that the focus of mathematics instruction has been on choosing the correct answer from multiple choice problems. No effort was spent by teachers on developing their students' critical thinking skills and dispositions. In addition, teachers did not show their students how to behave as critical thinkers and therefore there was no critical thinking model available for students to see, eveluat, and immitate in the classroom. Therefore, it is make sense if students are at non-critical thinkers stage (Dam & Volman, 2004).

The author believes that problem solving activities have the potential to help students improve their critical thinking skills and dispositions. Tumkaya, Aybek, & Aldag (2009) stated that a better disposition toward critical thinking is associated with greater problem solving skills. In fact, Polya (1973) already provides a room for developing critical thinking during problem solving activities. One stage of the Polya four-stages problem solving, i.e. *looking back* stage, is devoted to develop critical thinking skills. At this stage, problem solvers are encouraged to monitor and evaluate their understanding of the problem, the process of identifying the most appropriate problem solving strategy or plan to solve the problem, and the process of performing mathematical concepts, rules, and algorithms during the plan implementation. If they are encouraged to reflect and use reasoning skills to check the correctness of their solution process, and explore other points of views that can be used to solve the problem more effectively and efficiently, there is a chance for us to help students to become better critical thinkers. Therefore, optimizing the implementation of Polya four-stages problem solving activities can be used to improve prospective mathematics teachers' critical thinking skills and dispositions.

Actually, choosing the correct answer from the multiple choices problems can also be utilized as a tool for developing critical thinking. Choosing the correct answer requires cognitive activities too, and this can be used to improve students' thinking if the learning process is focused on learning to think (Thompson, 2011). If the teachers could encourage their students to *always* monitor and evaluate their thinking processes during choosing the correct answer, students' critical thinker level can be improved. This is inline with Lai (2011) who stated the need of the integration of cognition and attitude to help students develop their critical thinker level.

One more thing that the author wants to propose for developing critical thinking dispositions is to use of questioning skills during mathematics instruction. Asking students to reflect and evaluate their own statement will enable them to develop several characteristics of critical thinking dispositions, such as: truth-seeking, analyticity, and open-mindedness dimensions (Browne & Keely, 2007; Broadbear, Jin, & Bierme, 2005). Reflective questions used in these case studies has shown us that the potential. Therefore, in case of mathematics education, the author also encourages mathematics teachers to frequently confront their students with any claim, and ask them to raise as many as possible questions to investigate the truth of the claim. Asking the possible assumptions or the universal set of its variable from incomple information problem could help the students develop their critical thinking skills and dispositions.

CONCLUSION

Finally, the three case studies suggest that the critical thinking disposition stage of Indonesian prospective mathematics teachers is mostly at the lowest stage, namely *Non-Critical Thinker level*. Therefore, it is recommended that curriculum and instructional practices at teacher education institutions should be revisited. Teaching problem solving and critical thinking skills, and modeling critical thinking dispositions are among instructional practices that should be prioritized in daily pre-service mathematics learning. Teacher educators should also conducting follow up studies to investigate the best practice which improve prospective mathematics teachers' critical thinking skills and dispositions.

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