

Analysis of Critical Thinking Skills in Solving Mathematical Problems in Terms of Field Independent and Field Dependent Cognitive Styles

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Abstract

This study aims to describe critical thinking skills in solving mathematical problems in terms of Field-Independent (FI) and Field-Dependent (FD) cognitive styles. This type of research is descriptive qualitative research. This research was conducted at a state Islamic senior high school in Bantul, Special Region of Yogyakarta, Indonesia. The results of the analysis showed that the Critical Thinking Level (TBK) was 0, namely students did not meet all Ennis indicators through the Polya problem-solving process, namely understanding the problem, planning ideas, implementing ideas, and re-examining. TBK 1, namely students who meet two or three of Ennis' indicators through the Polya problem-solving process: the ability to understand problems; able to plan ideas; unable to implement ideas; and unable to re-examine. The difference between FI and FD students in this category is that FI students tend to be more able to improvise than FD students. TBK 2, namely students who met four of Ennis' indicators through Polya's problem-solving process: The ability to understand problems, the ability to plan ideas, the ability to implement ideas, and unable to re-examine. The difference between FI and FD students in this category is that FI students tend to pass these indicators better than FD students. While TBK 3, namely students who meet all Ennis indicators through the Polya problem-solving process. The difference in solving problems is that FI students can use their language while FD students do not. The conclusion is that students' thinking levels differ according to their cognitive styles.

Keywords: cognitive style, critical thinking, problem-solving

INTRODUCTION

Mathematics is one of the main subjects and can form a logical, systematic, critical, and creative mindset. This is in line with Ministerial Regulation No. 22 of 2006 concerning Content Standards for Primary and Secondary Education Units, which states that mathematics needs to be given to all students starting from elementary school to equip students with logical, analytical, systematic, critical-thinking skills, creativity, and collaborative ability. Therefore, one of the abilities that students should have is the ability to think critically.

Critical thinking is deep, logical, and reflective thinking continuously to improve the thinking quality and apply intellectual

standards in conclusion (Sumarmo et al., 2012). While critical thinking skills are evaluative thinking abilities that demonstrate the human ability to see the gap between reality and truth by referring to ideas and being able to analyze, evaluate, and solve problems wherever they are (Rachmadtullah, 2015). This ability is very important and must be possessed by individuals (Aizikovitsh-Udi & Cheng, 2015).

Individuals are often faced with making decisions that require reasoning, understanding, analysis, and evaluation of the information received so that critical thinking allows a person to make valid decisions. The ability to review critically is the first step that a person must take in dealing with problems,

obtaining information from problems, and using it to solve them (Faradina *et al.*, 2019). In addition, critical thinking skills are also very necessary when students are involved in community life. Critical thinking skills can help students adapt to the environment and be able to overcome problems in life. The reasons for the importance of developing critical thinking skills are: (1) demands of the times that demand everyone can search, choose, and use information for the life of society and the state; (2) everyone is always faced with various problems and choices so that they are required to be able to think critically and creatively; (3) the ability to see things differently in solving problems; and (4) critical thinking is an aspect of solving problems creatively so that someone can, on the one hand, compete fairly and, on the other hand, work together with other nations (Shanti *et al.*, 2018). Some of these descriptions show that critical thinking skills are very important, especially in learning mathematics.

This is in line with what was conveyed at the 2016 World Economic Forum, that the ability to think critically is one of the ten abilities that every individual must possess to win the competition in the future. However, in reality, critical thinking skills among students are predicted to be in the low category. This can be seen in the results of the PISA and TIMSS studies. PISA results from Indonesian students are ranked 62 out of 70 countries that took part in PISA in 2015. Indonesia obtained a score of 403 out of an average OECD score of 493 (Afriyanti, Wardono, & Kartono, 2019). Based on the results of the TIMSS analysis in 2011, the mathematics scores obtained by Indonesian students compared to the mathematics scores obtained by international students were far below the average. Only 17% had reasoning competence, a position that was ranked 36 out of 48 countries. The students' critical thinking skills were still low because several factors influenced them (Arif & Cahyono, n.d.).

To encourage students' critical thinking skills to improve and not be left behind by

other countries, students need to be given problems in mathematics. Critical thinking is a set of skills that can be used by someone to solve problems and create alternative problem-solving methods (Salahuddin & Syahrir, 2020). So, that when students are given a problem, what they will do is find a solution to solve the problem that has been given. Problem-solving is a person's process of responding to or overcoming problems whose solutions are not yet clear (Mayasari *et al.*, n.d.-a). Mathematical problem-solving is the process of applying previously acquired mathematical knowledge to new situations (Nurfatanah, Rusmono, & Nurjannah, 2018). The problem-solving steps according to Polya (Astutiani & Hidayah, n.d.) consist of four steps: (1) understanding the problem or understanding the problem (identifying important data that is known and the conditions of the problem); (2) making a settlement plan or devising a plan (planning several steps to be taken to solve the problem); (3) carrying out the plan for completion or carrying out the plan (implementing the plan that has been prepared previously); and (4) checking back or looking back (checking back the results of problem-solving that has been done).

Students can use various strategies in solving mathematical problems. Problem-solving strategies are heavily influenced by students' cognitive styles (Indah *et al.*, 2021). However, the cognitive style of students has not been considered by the teacher in the learning process. There are internal factors that have not been considered to improve the quality of learning, one of which is cognitive style (Widayanti, 2013). Each student in the learning process has the characteristics of different cognitive styles in receiving learning materials.

There are two cognitive styles of students, namely Field-Independent (FI) and Field-Dependent (FD), which explains that someone who has a FI style has the ability to abstract elements from the context or background from the context. The characteristics of students who have a FI

cognitive style include: (1) having the ability to analyze to separate objects from the surrounding environment so that their views will not be affected if the surrounding environment changes; (2) having the ability to organize objects that are not yet organized and reorganize objects that have been organized independently; (3) tending to be less sensitive, cold, keep a distance from other people, and individuality, characterized by interactions with other people carried out as necessary; (4) choosing a profession that can be done individually or independently with more abstract material or requires theory and analysis; (5) tend to define goals and work alone but likes to compete; and (6) tend to work with an emphasis on intrinsic motivation and is more influenced by intrinsic motivation (Wulan, 2019).

Meanwhile, students with a FD cognitive style: (1) tend to think generally or globally in problem solving and view objects as a unit with their environment so that their views are easily influenced by changes in the surrounding environment; (2) tend to accept the existing structure or organization because it cannot restructured; (3) have a social orientation so that they appear kind, friendly, wise, kind, and full of love for others; (4) tend to choose a profession that emphasizes social skills; (5) tend to stick to existing goals; (6) tends to work by prioritizing external motivation and is interested in external reinforcement, such as gifts of praise or encouragement from others; and (7) tend to cooperate with others and respect the opinions and feelings of others. So, it can be concluded that students who have a FI cognitive style have a high level of independence and tend to choose to study individually. Meanwhile, students who have a FD cognitive style tend to choose to study in groups and require motivation and reinforcement from others.

The FI and FD cognitive styles are important to analyze because the FI and FD cognitive styles are dependent on the learning carried out by the teacher (Rifqiyana, 2015). In addition, this cognitive style is also seen as one

of the determining variables of students' ability to solve problems. This cognitive style is suitable when associated with research that analyzes critical thinking skills in problem-solving.

There are research that are related to this study. Research by Hasanah (2017) that has been carried out related to critical thinking skills in problem solving; Maula (2019) that deals with problem solving in terms of cognitive style; and Riska (2020) that relates to the ability to think critically in problem solving in terms of student learning styles. However, there is no research linking critical thinking skills in problem solving in terms of field independence cognitive style and field dependence cognitive style.

Leaving from the background of the problem, researchers are interested in studying critical thinking skills in solving mathematical problems in terms of students' cognitive styles, especially *Field-Independent* (FI) and *Field-Dependent* (FD) cognitive styles. The research aims to describe critical thinking skills in problem solving mathematics in terms of field independent and field cognitive styles dependent.

METHOD

The type of research used is a type of research with a qualitative approach, meaning that it describes or describes events that are the center of attention, namely the ability to think critically in solving mathematical problems in terms of students' cognitive styles qualitatively and based on qualitative data. This research was conducted at a state Islamic senior high school in Bantul, Special Region of Yogyakarta, Indonesia. While the time of this research is in the even semester of the 2021/2022 academic year.

Data collection in this study was carried out in three stages, namely the GEFT test, the written test, and the interview. The first stage of data collection in this study was the GEFT (Group Embedded Figure Test) test. This test was held on Thursday, February 3, 2022, in class XII, a state Islamic senior high school in

Bantul, Special Region of Yogyakarta. 32 students take the GEFT test. The time for this test is 25 minutes, but in practice, this test is carried out for one hour of lessons or 35 minutes, namely 10 minutes to explain the subject regarding the instructions for using the test, and 25 minutes are used to work on the GEFT test.

The second stage of data collection in this study was a written test. This test consists of three essay questions with probability material in the sub-chapter of enumeration rules. The written test time is 60 minutes. Then the subject must work according to the completion steps provided on the answer sheet. During the process of taking this test, subjects are not allowed to open books or notes and are prohibited from cooperating with friends. This is done to determine the level of critical thinking ability for each subject. The number of subjects who took the written test of critical thinking skills was 32. This test was carried out by the researcher 3 times because the schools that were used as research sites used a limited face-to-face learning system.

The third stage is the implementation of interviews with selected subjects. The selection of interview subjects was based on the criteria for the representation of FI and FD cognitive styles from the GEFT test results and the level of critical thinking skills from the subject's written test. It is determined that each of these types has at least one subject. So the number of interview subjects in this study amounted to 10 subjects. The form of the interview in this study is semi-structured, so the researcher uses interview guidelines during the interview process.

The research subject selection technique used in this research is the purposive sampling technique. This technique is used if the researcher has certain considerations in determining the sample according to the research objectives. The first criterion is the selection of class XII because the material opportunities are studied at this level. The second criterion, the selection of subjects, was chosen based on the subject's willingness to

complete all stages of this study, namely the GEFT test to classify cognitive styles, a written test to classify students' critical thinking levels, and interviews to determine problem-solving abilities. The third criterion is that students have good communication skills to answer all questions at the time of the interview, as obtained by the researcher through information from the mathematics teacher who is in charge.

In this study, 32 subjects were willing to complete all these stages. The 32 subjects consisted of 17 women and 15 men who had an age range of 16-19 years. The subject of this research is a school at a state Islamic senior high school in Bantul, Special Region of Yogyakarta, Indonesia.

In this study, the data collection instruments used were as follows: 1) The GEFT test was given to the subjects to classify students' cognitive styles. This instrument did not go through the validation stage because the instrument adopted the GEFT test developed by Witkin with a validity and reliability of 0.84. This test consists of three sessions. The first session consisted of 7 questions, while the second and third sessions consisted of 9 questions each. 2) A written test containing questions on the probability material "counting rules" in the form of an essay and consisting of 3 questions. All questions used in this study have had an assessment (validation) process from experts, namely lecturers and mathematics teachers. So that the question is valid and can be used in this study. The test was used to obtain data on students' critical-thinking skills. 3) Interview guide. This guide was created to obtain direct data regarding the reasons and confirmation to students of the answers to the written test questions given and to determine the level of critical thinking of students in solving mathematical problems. The interview guide used in this study had an assessment process (validation) from experts, namely lecturers and mathematics teachers. So that the interview guidelines used are valid.

In this study, to determine students' critical thinking skills in solving mathematical

problems, Ennis uses critical thinking indicators, which will be associated with problem-solving steps according to Polya. The rules can be observed in Table 1.

Table 1. Indicators of Critical Thinking According to Ennis and Polya Problem-solving

Ennis Critical Thinking Indicators	Polya Problem-solving Steps
1. Formulate the main problems	1. Understand the problem
2. Revealing the facts	
3. Detect bias	2. Make a settlement plan
4. Reveal relevant arguments	3. Implement the settlement plan
5. Able to draw conclusions	4. Check back

The data analysis technique used consists of 3 stages, including 1) data reduction, 2) data presentation, and 3) conclusion. To test the validity of this research data using: 1) triangulation of sources, 2) persistence of observers, and 3) peer examination.

RESULT AND DISCUSSION

Of the 32 class XII students of a state Islamic senior high school in Bantul, Special Region of Yogyakarta, who performed the cognitive style classification test, 17 students were classified with a FI cognitive style and 15 students with a FD cognitive style.

It has been explained previously that the purpose of this research is to describe critical thinking skills in solving mathematical problems based on cognitive style. Therefore, based on the results of data analysis from test results and interviews, it is known that the research subjects representing two groups of students with different cognitive styles have different critical thinking processes in problem-solving.

Then, of the 32 grade XII students at a state Islamic senior high school in Bantul, Special Region of Yogyakarta, who were given three critical thinking test questions, the students who had a critical thinking level or

TBK 0 were four students; TBK 1 was nine students; TBK 2 was sixteen students; and TBK 3 was three students. In detail, it will be described as follows.

Critical Thinking Level 0 (TBK 0) with FI dan FD Cognitive Style

FI and FD students with TBK 0 ability have the following characteristics: At the stage of understanding the problem, FI and FD students are not able to express what is known and asked in the question. At the stage of planning a settlement, FI and FD students are less able to express or determine the procedures used in solving problems. However, the FI student at the stage of planning for this settlement was able to express his plan even though the plan he made was wrong. Meanwhile, FD students are not able to express the plan of completion that they have made.

At the stage of implementing the plan, FI and FD students have not been able to apply the procedures that have been chosen to solve problems correctly and correctly. The student cannot carry out the plan according to what he has planned because of the student's lack of knowledge about the probability of "counting rules". The students are unable to solve the problems that have been planned due to a lack of student knowledge about existing concepts (Maula, 2019). Likewise, at the stage of re-checking the answers, it has not been carried out, so there is no conclusion on the answers of students with TBK 0.

Based on the results above, and following the research conducted by Hasanah (2017), the lowest level of thinking according to Ennis is TBK 0, that is, there are no answers that match the critical thinking indicators according to Ennis. In this study, FI and FD students with TBK 0 were only able to work on questions but did not meet the critical thinking indicators according to Ennis and got results that were not appropriate. The lowest level of thinking is the skill of memorizing (recall thinking), which consists of almost automatic or reflective skills (Mayasari et al.,

n.d.-b). So FI and FD students with TBK 0 or the lowest are only limited to memorizing skills without being able to understand concepts well.

Critical Thinking Level 1 (TBK 1) with FI dan FD Cognitive Style

FI and FD students with TBK 1 ability have the following characteristics: in understanding the problem, FI and FD students can reveal what is known and what is asked in the problem. In this case, it means that students can identify the facts in the problem and can formulate the main problem clearly and precisely.

Some students begin to be able to express their ideas and plans at the stage of planning for completion. But he did not carry out the plan based on his idea. This is due to the lack of students' knowledge of the probability material "counting rules". The students are unable to solve the problems that have been planned due to a lack of student knowledge about existing concepts (Maula, 2019). At this stage, FI students can illustrate the problems in the questions quite well. In addition, FI students tend to be more independent in solving problems. Meanwhile, FD students in illustrating problems on questions tend to be less able to improvise. Students who have the FI cognitive style tend to be able to illustrate problems quite well and are more independent in solving problems, while students who have the FD cognitive style tend to still depend on information from teachers or other people (Hasanah, 2017).

At the stage of implementing the plan, FD students also have not been able to express plans or strategies to solve problems. Then at the re-examination stage, FI and FD students have not been able to re-examine, so there is no conclusion on the answers of students with TBK 1.

So it can be concluded that students who have TBK 1 students' answers are following two or three critical thinking indicators. The level of basic thinking skills (basic thinking), or in this case, TBK 1

includes understanding concepts such as addition, subtraction, and so on, including their application in questions (Mayasari *et al.*, n.d.-b). So students with TBK 1 are only limited to understanding the questions.

Critical Thinking Level 2 (TBK 2) with FI dan FD Cognitive Style

FI and FD students with TBK 2 ability have the following characteristics: when understanding the problem, FI and FD students can express what is known and what is asked in the question easily and precisely. In this case, it means that the student can identify the facts in the problem and can formulate the main problem clearly and precisely. Then, at the stage of making and implementing a settlement plan, FI and FD students can show a strategic plan and interpret the plan to solve the problem. However, FD students were less able to explain the plans that he made. This is because students only memorize concepts or what they have already learned. That FD students have the characteristic of being unable to improvise in solving problems. So what will be done is only memorize concepts that have been understood (Hasanah, 2017). At this stage, FI students are better than FD students at illustrating the problems in the questions. However, in re-checking the answers to the results of the completion of the FI and FD students, they have not done so. So there is no conclusion to the answer with TBK 2.

Based on the results above, it is in line with the four indicators of Ennis. Starting thinking is when the thinker begins to modify some of his thinking abilities but has limited insight (Fatmawati, Mardiyana, & Triyanto, 2014). They lack systematic planning to improve their thinking skills. Thinking exercises (practicing thinking) are thinkers who actively analyze their thinking in some fields, but they still have limited insight into deep levels of thinking. In this case, initial thinking and practicing thinking are included in TBK 2. So that students can analyze their thoughts on a problem but not in-depth.

Critical Thinking Level 3 (TBK 3) with FI dan FD Cognitive Style

FI and FD students with TBK 3 ability have the following characteristics: At the stage of understanding the problem, FI and FD students can easily and precisely express what is known and what is asked in the question. In this case, it means that students can identify the facts in the problem and can formulate the main problem clearly and precisely. However, FI students tend to be able to process information from questions in their language. Individual FIs can implement their structure (Prabawa & Zaenuri, 2017).

At the stage of planning and implementing the plan, FI and FD students can show the strategic plan and interpret the plan to solve the problem. However, FD students were less able to explain the plan and the results of the plan. This is because students do not understand the concept of probability material "counting rules". So FI students with TBK 3 have a better ability to solve problems. Students with the FI cognitive style tend to be able to solve problems well and smoothly (Desmita, 2019). Because basically, independent students can decipher complex problems into simpler ones so that they are easy to solve.

Furthermore, at the stage of re-checking, FI students can re-examine the results of their answers. This can be seen from the explanation he gave related to what he had written. Meanwhile, FD students have also been able to re-examine but are less able to explain what he wrote. In addition, the conclusions he wrote were incomplete.

Based on the above results, this is in line with the opinion (Fatmawati, Mardiyana, & Triyanto, 2014) that advanced thinking is an active thinker who analyzes his mind and has important knowledge about problems at a deep level of thinking, but they have not been able to think at a higher level consistently in all dimensions of life. Superior thinking (accomplished thinking) is a thinker who internalizes the basic ability to think deeply. Critical thinking is done consciously and uses

high intuition. In this case, advanced and superior thinking are included in TBK 3 so that students with TBK can think deeply and have broader insights. Students with TBK 3 write in detail each step of completion, examples of questions, and questions given by the teacher. Students with TBK 3 discuss a lot with their classmates and often try to work on questions. The differences in TBK 0, TBK 1, TBK 2, and TBK 3 of FI and FD students are presented in Table 2.

The work done by these students is influenced by differences in cognitive styles. This is in line with the opinion (Rusman & Cepi, 2012) that physiological and psychological factors can affect a person's learning outcomes. One of the factors related to psychology is cognitive style. Based on the results that have been carried out by researchers, there are differences in critical thinking skills in solving problems between students with FI and FD cognitive styles. The difference can be seen in the process, way of thinking, and calculation steps of the two cognitive styles.

Each type of cognitive style has different characteristics in the ability to think critically at solve problems. However, this ability can be used to make students more skilled in solving problems. As (Herlambang, 2013) suggests, problem-solving is needed if a person wants to achieve certain goals but does not yet know how to solve them. So, if someone is trained to solve a problem, then he will have good skills in processing information to obtain the appropriate solution.

Efforts to maximize critical thinking skills in solving student problems certainly cannot be separated from the learning process in the classroom. Therefore, educators, in carrying out the learning process, need to consider the learning strategies that will be used. The learning strategy in question is a learning strategy that can be accepted by students with FI and FD cognitive styles.

Table 2. Differences in TBK Based on Cognitive Style

	FI Students	FD Students
TBK 0	At the stage of understanding the problem, students are not able to uncover the facts and formulate the main points of the problem At the stage of planning a solution, students are not able to find the right idea but are already looking for the idea they made At the stage of implementing the plan, students are not able to solve the problem At the re-examination stage, students are not able to solve the problem	At the stage of understanding the problem, students are not able to uncover the facts and formulate the main points of the problem At the stage of planning a solution, students are not able to find and find the right idea At the stage of implementing the plan, students are not able to solve the problem At the re-examination stage, students are not able to solve the problem
TBK 1	At the stage of understanding the problem, students can uncover the facts and write down the main points of the problem clearly and use their language At the stage of planning a solution, students can find ideas to solve problems At the stage of implementing the plan, students are less able to solve problems At the re-examination stage, students are unable to check answers and cannot conclude	At the stage of understanding the problem, students can reveal the facts and write down the main points of the problem clearly, and tend to use the language presented in the problem. At the stage of planning a solution, students can find ideas to solve problems At the stage of implementing the plan, students are less able to solve problems At the re-examination stage, students are unable to check answers and cannot conclude
TBK 2	At the stage of understanding the problem, students can uncover the facts and write down the main points of the problem clearly and use their language At the stage of planning completion, students can find solutions using their ideas At the stage of implementing the plan, students can solve problems and can express the reasons At the re-examination stage, students are not able to conclude and check answers	At the stage of understanding the problem, students can reveal the facts and write down the main points of the problem clearly, and tend to use the language presented in the problem. At the stage of planning for completion, students can find solution ideas according to what they have learned before At the stage of implementing the plan, students can solve the problem but are unable to express the reason At the re-examination stage, students are not able to conclude and check answers
TBK 3	At the stage of understanding the problem, students can uncover the facts and write down the main points of the problem clearly and use their language At the stage of planning completion, students can find solutions using their ideas At the stage of implementing the plan, students can complete the solution in their way At the re-examination stage, students can conclude answers and re-check	At the stage of understanding the problem, students can reveal the facts and write down the main points of the problem clearly, and tend to use the language presented in the problem. At the stage of planning a solution, students can find solution ideas using what they have learned before At the stage of implementing the plan, students can complete the completion according to what was taught by the teacher At the re-examination stage, students can conclude the answers

The strategy can be started with the teacher presenting various problems to students and then guiding students to plan strategies for solving these problems. In addition, teachers can also understand students' thinking processes and can guide and help students to be more skilled in solving problems.

Problem-solving skills can be developed through providing experience or submitting problems that require various strategies from one problem to another (Asfar, 2018). Thus, the learning strategy of presenting the problem is expected to facilitate students' thinking and acting independently in solving the problems they face.

Teachers can use a learning model to improve students' critical thinking skills in solving problems (Boru, 2017). The learning model that fits the Field Independent cognitive style is the Team Games Tournament (TGT) learning model. This follows the characteristics of the field-independent cognitive style with the ability of students to think both proactively and reactively, being able to search, select, and receive information so that they can solve the problems encountered. The learning model that is suitable for the field-dependent cognitive style is direct because students with a field-dependent cognitive style are more comfortable and fit in a structured environment, following existing goals, prioritizing motivation, external reinforcement, and guidance or instructions from the teacher.

Based on this description, it is clear how important critical thinking skills are in problem-solving and that every student must have. This is done not only in the field of education but also in everyday life. The results of this research should be a good concern for students, teachers, schools, and related parties to continue to improve the quality of learning, especially those related to students' critical thinking skills in solving problems.

CONCLUSION

The critical thinking process of students in problem-solving in terms of cognitive style

is that FI and FD students who can TBK 0 are unable to fulfill Ennis' five critical thinking indicators through the problem-solving process. But the FI student can reveal the completion plan he has made. Meanwhile, FD students were not able to express their plans. FI and FD students who have TBK 1 ability are only able to fulfill two or three indicators of Ennis' critical thinking through the problem-solving process. However, FI students tend to be better able to improvise in understanding and planning ideas. FI and FD students who have TBK 2 ability are only able to fulfill Ennis' four critical thinking indicators through the problem-solving process. However, FI students tend to be able to understand problems, make plans, and implement plans better than FD students. FI and FD students who have TBK 3 ability can meet all of Ennis' critical thinking indicators through the problem-solving process. However, FI students are more likely to be able to solve problems using the language in the questions. In addition, FI students can also express other reasons and ideas for solving problems.

The suggestions from this study are (a) for teachers, it is recommended to develop mathematics learning that dea state Islamic senior high school in Bantul, Special Region of Yogyakarta's critical thinking skills in solving mathematical problems, for example by choosing learning strategies that can be accepted by students with FI and FD styles, namely by paying attention to learning models that are suitable for students. With FI and FD styles, (b) for researchers, it is hoped that research can be carried out in the long term.

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