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Using Guided Inquiry Learning with Multiple Representations to Reduce Misconceptions of Chemistry Teacher Candidates on Acid-Base Concept

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Abstract

The aim of this study was to reduce misconceptions chemistry teacher candidates using guided inquiry learning with multiple representations. The study was carried out with the participation of a total of 69 chemistry teacher candidates at the chemistry department, State University of Gorontalo. Data were collected using three-tier diagnostic test with a 24-item test to solicit students misconceptions on the concept of acids and bases. Tests were given to another group of students at the same level and the coefficient of reliability (Cronbach's alpha) was 0.71. Validity of the tests have been evaluated by expert validator. The results showed that guided inquiry learning with multiple representations have succeeded to change students understanding into knowledge of correct concept..

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INTRODUCTION

Chemistry is a subject based on concepts, many of which are abstract and are therefore hard to grasp and learn especially when the students are put in a position to believe without seeing (Stojanovska et al. 2012). On the other hand, students are basically familiar with a number of relevant concepts as a result of their previous learning (Roschelle, 1995). The potentially present preconceptions about the world itself can be reflected in the chemistry lessons and can sometimes grow into misconceptions.

Misconceptions require greater attention in chemistry learning (Chittleborough and Treagust, 2007; Horton, 2007). Misconceptions that tend to occur in chemistry can cause students are less successful in applying these concepts to new situations suitable and in turn students may fail to learn the concepts of chemistry. This is consistent with the statement of the researchers in the field of cognitive psychology suggests that the occurrence of misconceptions in the initial concept will become a barrier to the ability of the next academic process (Unal, costumers, and Ayas, 2010; Metin, 2011). Therefore, knowing the misconceptions possessed by students to be very important and pursued further learning model to prevent and reduce them.

Many studies in the field of chemical misconceptions and difficulties in learning and understanding chemical concepts have been reported (Canpolat, 2006; Demeroutietal. 2004; Demircioglueta l., 2005; Chiu, 2005; Cliff, 2009; Calyketal., 2005; Kariper, 2011; Costuetal. 2010; Taber, 2011). Several studies have found that misconceptions have occurred in some chemical concepts such as acid-base (Yalcin, 2011; Metin, 2011; Bilgin, 2009), the equilibrium acid base (Demerouti et al. 2004, Metin et al. 2011), evaporation (costumers, Ayas, and Niaz 2010), the reaction rate (Kaya and Geban, 2012), colligative properties (Pinarbasi et al. 2009) and chemical bonds (Pikoli et al. 2004).

Alternative conceptions of the students will be reconstructed during the learning activities (Nakiboglu, 2003). The results of the reconstruction process of the student studying chemistry among others, is the understanding of scientific concepts. However, if the learning outcomes of students in chemistry is still quite low, meaning the concepts of chemistry yet well understood and mastered by students. Even today there is suspicion that says that the chemical subjects in school is a difficult subjects studied (Sirhan, 2007; Wood, 2006). One cause of these difficulties because the subject matter many chemical abstract (Levy, Mamlok, and Hofstein, 2007; Yalcin, 2011) and the students had misconceptions in distinguishing the concept macroscopic and microscopic (Chandrasegaran et al. 2007; Pikoli and Sihaloho, 2007, Pikoli et al. 2014, and Pikoli et al. 2016).

Build understanding of chemical concepts can be done by using multiple representations, namely the representation of macroscopic, submicroscopic and symbolic (Hilton and Nichols, 2011; Gilber, 2009; Sirhan, 2007). But in general chemistry learning that occurs at this time is focused on two levels, namely the macroscopic and symbolic representation and neglect that could cause misconception submicroscopic (Stojanovska et al. 2012). Other researchers have also argued that the inability of students to make the correct relationship between the three levels of this representation is the cause of misconceptions (Unal et al. 2010). In the practice of learning activities, the integration of multiple representations macroscopic, submicroscopic and symbolic handed over to the students themselves to understand it without the guidance and direction of the teacher. Sirhan (2007) reported that students have difficulty connecting the three levels of representation macroscopic, submicroscopic and symbolic. The same thing also expressed by Levy et al., (2010) and Taber (2001) that the student does not have a deep conceptual understanding of chemistry concepts. The inability of students to represent chemical phenomena on the submicroscopic level could prevent the ability in solving chemistry problems associated with macroscopic and symbolic aspects (Chandrasegaran et al. 2007; Chittleborough and Treagust 2007; Talanquer, 2011). Other research also revealed that most students have difficulty understanding abstract concepts chemistry at the level of particulate or submicroscopic (Ya-Wen and She, 2009; Chittleborough and Treagust, 2007; Hilton and Nichols, 2011).

The difficulties of students in representing the chemical phenomena are caused by not trainedstudents in learning with submicroscopic representation. This is not in accordance with the characteristics linking chemistry between the three levels of representation should be explicitly taught (Treagust and Chandrasegaran 2009; Stojanovska et al. 2012). Further Devetak and Glazar (2010) found that students who have not been trained with external representation will have difficulty in integrating submicro structure of a molecule. Therefore, the learning of chemistry should be done by connecting the three levels of the chemical representations to improve the understanding of chemical concepts and prevent misconceptions that occur in students.

One of the chemical topic requiring the ability of students connect the three levels of representation is acid-base chemistry. This topic is one of the basic concepts in chemistry because most chemical reactions is an acid-base reaction. But most students still have misconceptions about the acid-base (Cetingul and Geban, 2005). Explanation of this concept carried through macroscopic representation as through practice can not show the actual changes that occur at the submicroscopic level. The introduction of this concept is generally represented macroscopically and symbolic.

Various studies have been conducted declare misconceptions students associated with acid-base among others Cetingul and Geban (2005) states that (1) any substance containing atoms H is an acid, a molecule containing OH is a base, (2) a strong acid has a pH higher than the weak acid, (3) a strong acid only react with a strong base and weak acid only react with a weak base, (4) reaction of acid and base is always a neutral solution. Demircioglu et al. (2005) reported that students had misconceptions on acid-base concept, namely (1) a solution of strong acid does not dissociate in water, because of the bond intramolecular very strong, (2) if the pH value increases, acidity also increases, (3) if the increased number of hydrogen atoms in a formula acidic, the acidity is becoming stronger. Devetak et al. (2004) also reported that the first year students have difficulty in to describe particulate scheme and changesubmicro representation to symbolic on acid-base equilibrium.

From the results of these studies, allegedly misconceptions and difficulties experienced by students due to lack of development of active learning that engages students and connect with submicroscopic representation. The assumption is reinforced reality on the ground and literature review that the teacher in the learning activities are still limited to the macroscopic level and symbolic. Devetak and Glazar (2010) states that submicroscopic representation is a powerful tool to identify misconceptions about chemistry concepts and to produce appropriate mental models of chemical phenomena which are stored in long term memory of students. Based on this, providing guidance for students is needed in learning activities. Lessguidance or no guidance during the learning is usually less effective than enough guidance, there is also the possibility to give effect to such students acquire knowledge is incomplete, causing misconceptions (Kirschner et al. 2006). Therefore, activity of students by connecting the three levels of representation of the macroscopic, submicroscopic and symbolic would be maximized if delivered in the appropriate learning models such guided inquiry learning model oriented.

METHOD

The design used in this study is one group pretest-posttest design. The sample consisted of 69 students (35 students of the class A and 34 students of the class B) who are chemistry teacher candidates at thechemistry department, State University of Gorontalo. Data collectionused three-tier diagnostic test form with a 24-item test to solicit student misconceptions on the concept of acids and bases. Tests given to another group of students at the same level and the coefficient of reliability (Cronbach's alpha) was calculated to be 0.71 and the validity of the tests have been evaluated by expert validator.

Data of reduction misconceptions students analyzed by using the guidelines on Three-tier diagnostic test imposed on the pretest and posttest. Based on the analysis of three-tier diagnostic test, misconceptions students divided into three category i.e misconceptions 1 (MK1), misconceptions 2 (MK2), and misconceptions 3 (MK3). Turker (2005) states that students MK1 and

MK2 are students who have an incomplete understanding of the concept, while the MK3 students are student who really experienced misconceptions. Arslan et al. (2013) stated MK1 as negative misconceptions and MK2 as a positive misconceptions.

Three-tier diagnostic test that is given at the posttest to determine the shift in the conception of students from MK1, MK2, MK3, and lack of knowledge (TTK) into knowledge of correct concept (TK). Reducing misconceptions students to know the decrease percentage of MK1, MK2, and MK3. The percentage of students who know the concept also give illustrating an improved understanding of the concept which is indicated by a score of *N*-gain. Data analysis was obtained from the students' answers of three-tier test.

RESULT AND DISCUSSION

Guided inquiry learning with multiple representations is expected to reduce the misconceptions students or shift misconceptions (MK1, MK2, MK3) into TK. Reduction of misconceptions can be viewed from the shift of misconceptions, both individually and group of students (class).

Reduction of individual students misconceptions

The comparison data of percentage of students conceptions before and after learning on acid-base concept by using guided inquiry with multiple representation is presented in Figure 1.

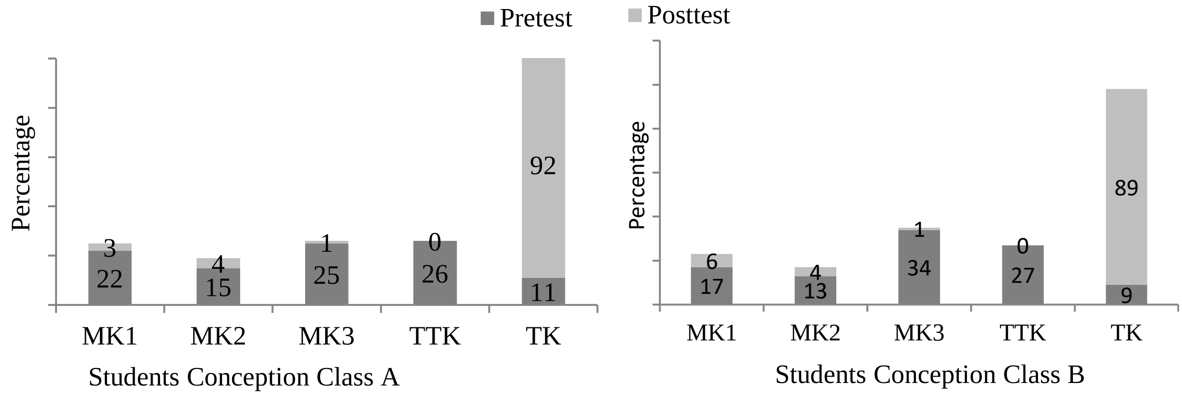

Figure 1. Percentage of students conception before and after using guided inquiry learning with multiple representations in class a and class b

Based on figure 1 shows that the student has left many miscoceptions about the concept of acid-Base in class A and class B. Overall, the percentage of students with TK on the concept of acid-base has reached 92% in class A and 89% in class B. The percentage of students who have misconceptions (MK3) dropped dramatically, as well as students with TTK. These facts indicate that the implemented learning can change student conception, which is from MK and TTK into TK. *N*-Gain result of increasing students conception shown in figure 2.

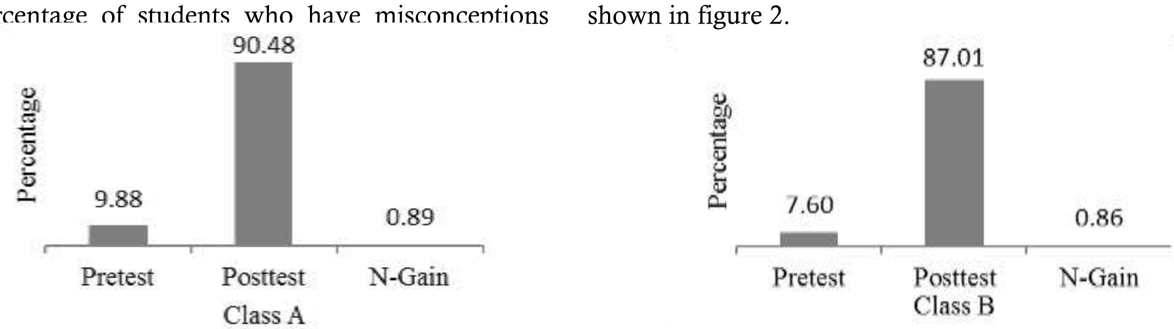

Figure 2. *N*-Gain scoreand percentage of pretest and posttest results of students class A and B.

Based on figure 2 there are increasingstudents conceptionbefore and after using guided inquiry learning with multiple representations. Overall *N*-Gain scorethat obtained is above 0.7, which means the category is "high." This indicates that guided inquiry learning with multiple representations capable to change student misconceptions (MK1, MK2, MK3) and TTK intoTK.

There are also students with MK3 type shift into MK2 or MK1 type. However there are students still remain on their misconception type. For further analysis, percentage of shifting students conception was calculated and the results are shown in diagram pastle as can be seen in figure 3 and 4.

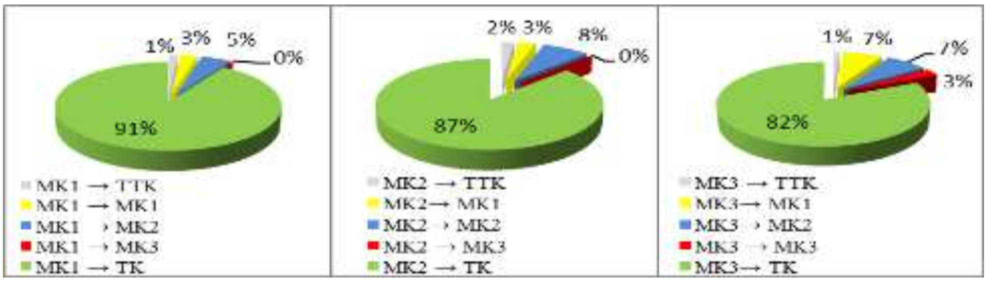

Figure 3. Conception shift of class A students in understanding acid-base concept

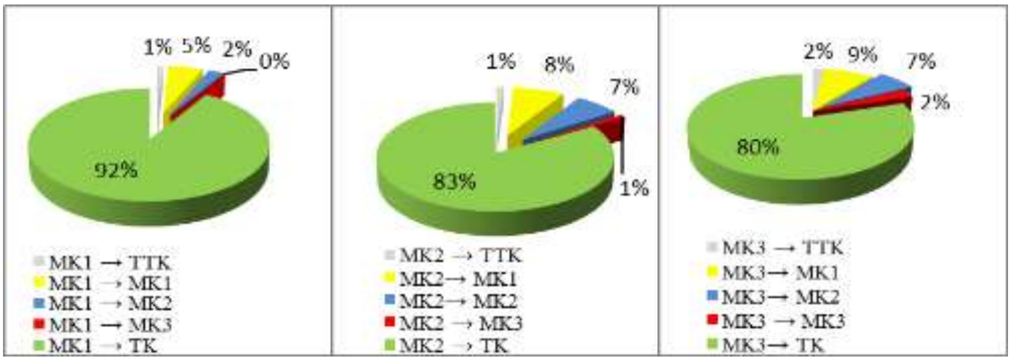

Figure 4. Conception shift of class B students in understanding acid-base concept

Based on the result in figure 3 and 4, there are several analysis that can be concluded as the following:

1) shift of students conception from MK1 toward TK are in very high category in both implemented class although there are students still with the same conceptionas before i.e remain in MK1 type (3% to 5% of class A and class B).
2) shift of students conception from MK2 towards TK are in high category in both implemented class, but there are still 8% of the students of class A and 7% of the students class B still remained with MK2.
3) shift of students conception from MK3 towards TK are in high category in both implemented class, but there are still 3% students of class A and 2% of the students class B still remained with MK3. In addition shift of students conception from MK3 to MK1 and MK2 is also occurred. It is revealed that students with MK3 conception are more more difficult to change their misconceptions.
4) Student with MK1 have highest percentage of changing their conception into TK compared than students with MK2 and MK3. While student with MK1 have lowest percentage. These fact indicates that to change misconceptions (MK3) into TK is more difficult than the MK2 and MK1.
5) Based on the descriptive analysis in figure 3 and 4, it can be said that (i) guided inquiry learningwith multiple

representations that addressed to reduce misconceptions chemistry teacher candidates have succeeded to change student concept intoTK, (ii) but overall, guided inquiry learning with multiple representations can not be able to reduce misconceptions chemistry teacher candidates.

Reduction of group of students (class) misconception after using guided inquiry learning with multiple representations

The analysis of misconceptions for a group of students (a class) proceeds in the same manner as described before for a student (individually). Comparison of this changes in both class presented in Table 1.

Table 1. Comparison of misconceptions reduction for a group of students.

Students Conception	Misconception Number of Students Class A		Misconception Number of Students Class B	
	Before	After	Before	After
MK1	110	16	78	27
MK2	75	18	62	20
MK3	142	3	164	5

Based on the data in table 1 there are reduction of student misconceptions (MK1, MK2, MK3) on the concept of acid-base solution in the class A and class B. Another point that can be interpreted from these data is the students who initially with MK3 shifted to MK1 and MK2 , therefore the number of students with MK1 and MK2 are still found in greater amounts than the MK3 as shown in figures 3 and 4. Based on descriptive analysis, we can concluded that there has been misconception reductionof group of students on the concept of acid-base solution either in class A and class B.

Conceptual change is part of a learning mechanism that requires learners to change the conception of a phenomenon through restructuring or integrating new information into existing schemata. More specifically Chi (2008) suggests that conceptual change is changing the meaning of a concept that has been held toward more scientific conceptions. Furthermore Hewson (1992) argues that conceptual change is replacing misconceptions with conception scientists more scientific. Based on these opinions, the conceptual changes are discussed in this section include a shift in the conception of student status MK1, MK2, MK3, and TTK towards TK, and the reduction of misconceptions (MK1, MK2, MK3) after the application of learning with guided inquiry with multiple representations described as follows.

Using guided inquiry learning with multiple representations have succeeded to shift conceptions of students with TTK, MK1, MK2, and MK3 towards TK. Furthermore, there are no students with TK change their conception to other types of conception. In addition there are some students are still remain in misconceptions or shifted to other types of misconceptions.

Based on figure 3 and 4 shows clearly that the number of students who have misconceptions (MK1, MK2, and MK3) and TTK have been reduced drastically and transformed into a TK after administiring with guided inquiry learning with multiple representations. These result are supported by both *N*-Gain scores (that are in the high category) and the mapping analysis of students conception before and after learning. The results of mapping student conception facilitate researchers in analyzing the type of MK1, MK2, MK3, and TTK on each student.

Figure 3 and 4 also illustrated that all students have a conception (MK1, MK2, MK3, and TTK). After administered with guided inquiry learning with multiple representations, the numbers of students with MK1, MK2, MK3 and TTK have been reduced drastically. Nonetheless, there are studentwho had MK1, MK2, and MK3 type with a small percentage. This results appropriate with the opinion of Hilton and Nichols (2011) and Suparno (2005) which states that to change misconceptions is something difficult. Ibrahim (2012) also argued that even if the true concept has been introduced to the students, there is still a chance of returning to misconceptions. Furthermore, based on Piaget's theories that waswritten by Suparno (2000), students who do not know the specific concept but have other schemes that can be developed with the assimilation process, will be easier to understand the concept. It is also found in this present study that the students with TTK more easily shift their conception into TK.

The success of the learning objectives using inquiry learning guided by multiple representation in shifting conceptions (MK1, MK2, MK3, and TTK) students rely on properimplementationof its syntax. Which is gives opportunity to students to actively process their information through inquiry guided to interconnect multiple representations. Devetak et al. (2009) found that students who had trained with submicroscopic chemical representation will be easier to interpret submicro structure of a molecule, so that the understanding of the phenomenon of chemical reactions will increase. Although guided inquiry learning with multiple representations can shift the conception of students from MK / TTK towards the TK, but there are still students who have difficulty in interconnect and transform representation from submicroscopic to macroscopic. The difficulties of these students can be avoided, because the students are still in the stage of practice using a variety of representations especially submicroscopic representations being studied (Sanger, 2005).

One example of students conceptual change from MK to TK that occurred in this studyis described below. At the initial stage, the students wrote their conception. One of the concepts that interpreted misconception is classifyingNH_3as an acid according to the theory of acid-base Arrhenius due to (1) NH_3 contain hydrogen (H) atoms, (2) capable to donate protons, (3) able to accept an electron pair, (4) capable to receive proton and (5) able to donate an electron pair. Furthermore there are students that classify C_2H_5OH as base according to Arrhenius acid-base theory for the same reasons as above. In addition there are also students who give other reason such as C_2H_5OH have OH group. At this stage, students weremotivated to learn further concept by featuring demonstrations that led to constructing of cognitive conflict. Students focus on the demonstration by observing a erlemeyer flask that was filled with NH_3 solution. The solution was dripped with phenolptalein indicators, thenstudents write down their observations. After conflict arises in their minds, students have asked to think about and give a further explanation of the concept according to the Arrhenius acid and why there are difference between their conception with the observations. Once students are motivated, individually, students were gave the opportunity to resume their conception through work sheets.

In the exploration phase, students discuss acid-base concepts by interconnect betweenmacroscopic, submicroscopic and symbolic representation used text books, websites, and direct observation. Concepts which gained from text books, were discussed and confirmed by direct observation and submicroscopic image/animation. Students at this stage attempt to align their conception if there are in appropriate between early conceptand their new concept. Based on their experiecing at exploration stage used text books, students write that according to the Arrhenius concept acid is a substance that when dissolved in water will produce H^+ ions, while bases are substances that when dissolved in water will produce OH^- ions. This concept is reinforced by the results of the study the students through the website that shows pictures of a substance containing the chemical formula of H atoms but the substance is not acidic substances as well as chemical formula containing OH but not base. This is also demonstrated through direct observation that NH_3 that dissolved in water can not change the color of litmus blue, but it can change the color of red litmus to blue which is a marker of base. Similarly, C_2H_5OH solution can not change the color of red litmus, but it can change the color of litmus blue to red which is a sign that the solution is acidic.

In the conceptualization phase, students presented their new concept through class discussion. At this stage the lecturer directs students to be active to explain their concept and guiding students to reconstruction their misconception and make conceptualization. Based on cognitive activity of students that was recorded in learning software, the results of conceptualization are according to Arrhenius, acid is a substance that when dissolved in water will produce H^+ ions, while bases are substances that when dissolved in water will generate OH^- ions. In addition not all substances that contain H atoms can act as acidic and not all chemical defined substances with OH groupis base. During the application phase, the students were given questions to apply the concept to interconnect multiple chemical representation based on concepts acquired through the conceptualization stage.

Reduction Misconceptions

Using guided inquiry learning with multiple representations success to reduce misconceptions chemistry teachers candidates from MK1, MK2, and MK3 towards TK. Reduction of these misconceptions can be analyzed individually and classically. Individually all students in the class A and class B has experienced a reduction of misconceptions both MK1, MK2, and MK3 and change to TK. Furthermore, there are no students with TK changed their conception to other types. It also was found that there are students remain in their misconceptions or shifted to other types of misconceptions. Classically guided inquiry learning with multiple representations can reduce students misconceptions both MK1, MK2, and MK3. Also there are students remain with misconceptions. This is reasonable because the learning was carried out with the same period of time for all students. Based on the theory of constructivism that students construct their knowledge, scheme, categories, concepts, and structure of knowledge have a different speed (Suparno, 2005).

Refer to figure 1 group of students with MK1 and MK2 easier to change their conception to TK than students with MK3. This results are consistent with other studies i.e Turker (2005) and Arslan et al. (2013) which proposed that the most resistant misconceptions is MK3, therefore it is very difficult to change students concept with MK3 type. Resistance of MK3 type can be seen in their shift pattern. There are students with MK3 shift their conception to TK and there are also to MK1 and MK2. So the numbers of students with MK1 and MK2 still higher than with MK3. Nevertheless, MK3 can be reduced with guided inquiry learning with multiple representations. Based on result as shown in table 1 there are concepts conceived by students had been reduced and transformed into TK. This is indicator for the success of guided inquiry learning with multiple representations to reducing students misconceptions on the concept of acid and base solutions both individually and classically (group of students). Therefore it can be concluded that the use of guided inquiry learning with multiple representations has managed to reduce misconceptions students on acid and base concepts.

CONCLUSIONS

Guided inquiry learning with multiple representations effective to change conceptions of students from MK1, MK2, MK3, and TTK to TK, which is indicated by increasing the percentage of chemistry teacher candidates withTK and high category of N-gain score. Guided inquiry learning with multiple representations effective to reduce students misconceptions both individually or in group of students (class), that indicated by the reduction of students misconceptions at high category.

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