Teachers’ activities during designing Higher-Order Thinking Skills (HOTS) mathematical questions through teacher assisting program

Wahyuni1,2, R Johar2 and M Dusiri3
1Educational Quality Insurance Institution, JL. Banda Aceh Medan Km 12.5, Aceh Besar 23361, Indonesia
2Syiah Kuala University, Jl. Teuku Nyak Arief Darussalam, Banda Aceh 23111, Indonesia
3Ar-Raniry State Islamic University, Jl. Syeikh Abdul Rauf, Banda Aceh, 23111, Indonesia
E-mail: rahmah.johar@unsyiah.ac.id

Abstract. Support for primary school teachers when designing mathematical questions would be crucial since many teachers were not able to develop mathematical questions that could train students to reach higher order thinking skills. This study aims to provide teachers with guidance in designing HOTS questions as a part of the development process of teaching instruments by using Plomp model. This paper only explains teachers’ activities during the assisting programs in the prototyping phase. The assisting programs were conducted in four meetings and involved ten primary school teachers in Banda Aceh, Indonesia. The findings showed that teachers' activities during the first assisting program in designing HOTS questions were not as effective as had been intended, due to the lack of teachers' attention to the tutor's instructions during the program. Meanwhile, the second assisting program showed an effective result on all components of teachers' activities. This program could potentially be applied to other mathematics topics involving many teachers, which is the main program in the next phase of this development research.

1. Introduction

HOTS involves a complicated thinking process, which does not offer a specific algorithm to solve a particular mathematical problem, it is unpredictable and uses different approaches from the previously existing problems [1]. Moreover, higher-order thinking is nonalgorithmic, that is, the path of action is not fully specified in advance, tends to be complex, often yields multiple solutions, each with costs and benefits, rather than unique solutions, involves nuanced judgment and interpretation, and efforts. There is considerable mental work involved in the kinds of elaborations and judgments require [2]. In other words, HOTS could train someone to think critically and creatively. The characteristics of HOTS are to solve mathematical questions without algorithm and to produce multiple solutions [1].

Many teachers were not able to develop higher order thinking skills. A study showed that when teachers were required to write a question representing the Higher-Order Thinking (HOT) category, 60% of the teachers were only able to write a question from the Lower Order Thinking (LOT) category [3]. Hence, an assisting program to help teachers in designing HOTS mathematical questions
would be necessary. The assisting program aims to provide enforcement and supports for teachers to improve their teaching professionalism in designing HOTS mathematical questions. The assisting program means to create a strategy of “making the best of the client’s resources” [4]. While several studies were conducted on designing HOTS questions [1,5,6,7], it seems that no study has been conducted to assist teachers in designing HOTS mathematical questions. This paper only explains the activities of teachers during the assisting programs. It is important to observe teachers’ activities during the assisting programs to yield an active learning environment. Also, observing teachers’ activities could monitor the effectiveness and efficiency of particular activities, as well as could optimize the educational goals that are intended for those activities [8]. In this study, the teachers’ activities include the activities of listening to the explanation, designing mathematical questions, paying attention to the colleagues’ explanations, asking questions, responding to questions, making conclusions and assessing irrelevant attitudes during the program [9].

2. Method
This study used a Research and Development (R&D) approach, involving a model of Plomp that consists of three main phases: the preliminary research, prototyping phase and assessment phase [10]. The preliminary research phase involved an analysis of the teaching requirements for the mathematical topics that would be taught. The result of this phase suggested that most of the teachers were not able to create the indicators for mathematical questions of the topics. This paper specifically only explains the prototyping phase. In this phase, teaching instruments were developed, including tests, lesson plans, powerpoint slides, and observation sheets on teachers’ abilities. This phase involved ten primary school teachers who were teaching at Year 5 in Banda Aceh, Indonesia. The teachers were selected, only those who were able to design mathematical questions on the level of C1 (knowledge) and C2 (comprehension) of Bloom’s taxonomy. The participating teachers had the initials of AW, NA, RW, AI, IW, NM, YA, RN, SI, and ID. The teachers were between 25-45 years old and had teaching experiences at least five years.

| No | The observed activities                                      | Relevance percentage (P) |
|----|--------------------------------------------------------------|--------------------------|
| 1  | Listening/paying attention to the tutor’s explanation       | 25%                      |
|    | Designing HOTS questions as instructed and guided by the tutor | 25%                      |
| 2  | Listening/paying attention to colleagues’ explanation      | 10%                      |
|    | Asking question(s)/ expressing idea(s) to the tutor or colleagues | 15%                      |
| 3  | Answering/responding to questions                           | 15%                      |
| 4  | Making a conclusion about particular concepts or procedures  | 10%                      |
| 5  | Irrelevant attitudes during the assisting program           | 0%                       |

The assisting programs consisted of two different programs and were conducted in four meetings, wherein each program for two meetings. At the end of each program, the teachers who were in “Fair” and “Poor” categories were interviewed, as a reflection on the teachers’ activities when designing HOTS questions. The interview result was used to improve the next meeting’s program. Teachers’ activities during the assisting program were observed by using observation sheets, which consisted of seven categories as shown in Table 1. There was one observer who examined the dominant activities
performed by the teachers during the program. The observer noted the relevant codes and numbers of
the teachers’ activities every 10 minutes. The observation data were analyzed using percentages. An
activity of teachers was effective once teachers could complete the activity at the time that was
allocated during the initial training, with a tolerance level of 5%. Table 1 shows the relevance of
teachers’ activities to the proper allocated time for each activity during designing HOTS mathematical
questions.

One of the activities during the first meeting in the assisting program was provided the
participating teachers with a pre-test to evaluate their prior knowledge. The tutor then presented the
teachers with the explanation of the assessment process of the knowledge domain using Bloom’
taxonomy from C1 to C3. The process included the assessment technique, assessment instruments,
classification of questions types, procedures of writing questions, and grading guidelines. After the
presentation, a 30-minute-question-and-answer-session was held for clarifications on the topic of
formulating questions on the knowledge domain. The teachers were then provided with a worksheet to
write questions for a written test, which also included the basic competency, topics, indicators of
competency accomplishment, indicators of the questions, question types, and the number of questions.
Each teacher chose one of the basic competencies from Year 5 textbook to design the questions. The
teachers then formulated the indicators of the questions based on the chosen basic competencies. The
tutor guided the teachers who found difficulties when formulating the indicators of the questions. At
the end of the first meeting, the tutor interviewed the teachers with difficulties in designing the
questions. The interview result suggested that some of the teachers were not able to differentiate
between the indicators of the questions and the indicators of competency accomplishment.

At the second meeting, the tutor conducted a presentation regarding the previous studies of HOTS
and designing HOTS questions by teachers. The presentation also showed the results of the national
examination of teachers’ competencies and the differences between LOTS and HOTS questions. After
the presentation, the tutor grouped the teachers, two teachers for each group, to discuss how to design
HOTS questions. At the end of the meeting, a post-test was posed to the teachers and the reflection of
the first program was also discussed together.

3. Results and discussion
Teachers’ activities during the first assisting program on designing HOTS mathematical questions
were not fully effective. This situation was because the teachers’ activities in designing HOTS
questions were not performed as intended and as explained by the tutor. Besides, the teachers did not
possess enough capability of designing HOTS questions. Meanwhile, teachers’ capability would be the
main factor in the success of designing HOTS questions. The results of teachers’ activities during the
assisting program are shown in Table 2a and 2b.

| No | Observation category | Percentage of teachers’ activities during the assisting program (%) | Percentage of ideal time (%) | Average (%) | Effectiveness based on ideal time |
|----|-----------------------|---------------------------------------------------------------|-----------------------------|-------------|----------------------------------|
| 1  | Listening/paying attention to the tutor’s explanation        | 28,9                                                          | 25                          | 26,6        | Effective                        |
|    | Designing HOTS questions as instructed and guided by the tutor | 17,8                                                          | 25                          | 18,9        | Not effective                    |

Table 2a. Teachers’ activities during the first assisting program.
Table 2b.

| No | Description                                      | Reflection | Findings | Revision                                      |
|----|--------------------------------------------------|------------|---------|-----------------------------------------------|
| 3  | Listening/paying attention to colleagues’ explanation | 13,3, 14,4 | 10%     | 13,8, Effective                               |
| 4  | Asking question(s)/expressing idea(s) to the tutor or colleagues | 18,9, 18,9 | 15%     | 18,9, Effective                               |
| 5  | Answering/responding to questions                | 11,1, 14,4 | 15%     | 12,7, Effective                               |
| 6  | Making a conclusion about particular concepts or procedures | 7,8, 7,8  | 10%     | 7,8, Effective                               |
| 7  | Irrelevant attitudes during the assisting program | 2,2, 0     | 0%      | 1,1, Effective                               |

Based on Table 2 the data suggested that the teachers’ activities in designing HOTS questions were not fully effective. Further, the unsatisfying findings of the first assisting program were revised and improved for the second assisting program. The revision of the first assisting program is shown in Table 3.

Table 3. Findings and revision of the first assisting program.

| No | Reflection | Findings                                                                 | Revision                                                                 |
|----|------------|--------------------------------------------------------------------------|--------------------------------------------------------------------------|
| 1  | Program I  | Some teachers did not fully pay attention during the assisting program in designing HOTS questions. Thus, the teachers’ activities did not run as efficiently as intended and instructed by the tutor. | The tutor encouraged and motivated all teachers to be able to design HOTS questions as had been instructed and guided before. The tutor also re-grouped the teachers and reset the sitting plan of the teachers, in order to encourage teachers to be more engaging during the assisting process |

Teachers’ activities during the first assisting program on designing HOTS questions were effective at level 85.7%. In other words, most of the activities have fulfilled the ideal time requirement. Only 14.3% of the teachers’ activities were not effective, in which the activity to design HOTS questions did not run as instructed and guided by the tutor. This ineffectiveness was caused by some teachers who did not fully pay attention to the assisting program in designing HOTS questions.

The second assisting program was conducted twice at the third and fourth meetings. At the third meeting, the tutor explained the classification of the complex thinking (Higher-Order Thinking). The discussion session was also held afterward, to discuss how to differentiate and use the operational verbs of Bloom’s taxonomy according to the cognitive level, as well as to relate the verbs to the indicators of HOTS questions. The last session at this meeting was that all the teachers tried to design HOTS questions. Furthermore, the second post-test was conducted at the fourth meeting, in which the teachers were asked to design HOTS questions consisted of level C5 of the Bloom’s taxonomy. After the post-test, reflection, and evaluation were held among the teachers.
The findings of the second assisting program showed that teachers’ activities in this program were effective, as the details could be explained in Table 4.

**Table 4. Teachers’ activities during the second assisting program.**

| No | Observation category                                                                 | Percentages of teachers’ activities during the assisting program (%) | Percentage of Ideal time (%) | Average (%) | Effectiveness based on ideal times |
|----|--------------------------------------------------------------------------------------|---------------------------------------------------------------------|----------------------------|-------------|-----------------------------------|
|    |                                                                                      | First meeting                                                                 | Second meeting               |             |                                   |
| 1  | Listening/paying attention to the tutor’s explanation Designing HOTS problems as instructed and guided by the tutor | 31,1                                                                                                | 17,8                          | 25%         | 24,5                              | Effective |
| 2  | Listening/paying attention to colleagues’ explanation Asking question(s)/ expressing idea(s) to the tutor or colleagues | 20                                                                                               | 32,2                          | 25%         | 26,1                              | Effective |
| 3  |                                                                                      | 13,3                                                                                                | 16,7                          | 10%         | 15                                | Effective |
| 4  |                                                                                      | 18,9                                                                                                | 15,6                          | 15%         | 17,2                              | Effective |
| 5  |                                                                                      | 10                                                                                               | 11,1                          | 15%         | 10,6                              | Effective |
| 6  |                                                                                      | 6,7                                                                                                | 6,7                           | 10%         | 6,7                               | Effective |
| 7  | Irrelevant attitudes during the assisting program                                      | 0                                                                                               | 0                             | 0%          | 0                                 | Effective |

According to Table 4 above, the observation findings showed that the teachers’ activities during the second assisting program on designing HOTS questions were effective. This effectiveness was indicated by the fulfillment of the ideal times requirement when the teachers designed HOTS questions. The involvement of the teachers during the assisting activities was believed as one of the factors that supported the improvement of teachers’ competency when designing HOTS questions at the second assisting program. During the assisting program, the teachers not only followed the tutor’s instructions but also designed the HOTS questions based on the academical theories they acquired from the tutor. As suggested by a study [11], to achieve success in a training program, the learning activities in training are supposed to be supported by involvement of the participants in all activities, including in planning, conducting, and assessing the learning activities of the training. Also, the use of the participative model in teacher training is believed to be more effective, because the main objects of the training are teachers who generally already have the prior knowledge.

This study suggested that the assisting programs that were conducted in two cycles seem likely to improve the teachers’ abilities to design HOTS questions. This idea is also relevant to the findings of a study [12], which showed an improvement in teachers’ abilities to conduct a classroom action research, after following an assisting program on a competency-based reflective classroom action research. Also, another study [12], showed that the abilities to design a classroom action research of a training’s participants could be optimized through tutorials, guidance, and assistance.

In this study, the observation of teachers’ activities during the assisting program was conducted by an observer. The recapitulation of the effectiveness of teachers’ activities during both of the assisting programs is shown in Table 5.
**Table 5.** The recapitulation of teachers’ activities during the first and second assisting programs.

| No | Observation category | Effectiveness based on the ideal times |
|----|-----------------------|--------------------------------------|
|    |                       | Program 1    | Program 2    |
| 1  | Listening/paying attention to the tutor’s explanation | Effective | Effective |
| 2  | Designing HOTS problems as instructed and guided by the tutor | Not effective | Effective |
| 3  | Listening/paying attention to colleagues’ explanation | Effective | Effective |
| 4  | Asking question(s)/ expressing idea(s) to the tutor or colleagues | Effective | Effective |
| 5  | Answering/responding to questions | Effective | Effective |
| 6  | Making a conclusion about particular concepts or procedures | Effective | Effective |
| 7  | Irrelevant attitudes during the assisting program | Effective | Effective |

Based on Table 4, only 85.7% of teachers’ activities during the first assisting program were effective, which suggests that not all activities on designing HOTS questions were successful as intended by the tutor. Meanwhile, at the second assisting program, the tutor emphasized on teachers’ participation in designing HOTS questions, by using the drilling method on the provided worksheets. This emphasis aimed to optimize the activity of designing HOTS questions as instructed and guided by the tutor, which was not effective in the first program.

The results of teachers’ activities during the second assisting program were relevant to the intended indicators, in which all of the teachers’ activities were effective. This relevance resulted from the active involvement of the teachers in designing HOTS questions. Also, the teachers were focused on the operational verbs of the Bloom's taxonomy for the cognitive level C4 to C6, when designing the indicators of the HOTS questions. These findings were relevant to a study [11], that suggested that learning or assisting process should be designed to yield potential circumstances for the participants to create effective learning activities. Moreover, group activities during the programs could allow the participating teachers to discuss, interact, and share their ideas with each other. The success of the second program also resulted from the interest, motivation, and determination of all teachers to improve their abilities to design HOTS questions. Some of the factors that could influence someone's success include intelligence, interest, attention, and readiness [12]. Besides, the factor of teachers’ prior knowledge, that teachers usually acquire from participating in seminars or training, might also be the supporting factor of the teachers’ success in designing HOTS questions.

4. Conclusion

In conclusion, based on the assisting programs that were conducted for four meetings, teachers’ activities during the first assisting program were ineffective at category designing HOTS questions as instructed and guided by the tutor. This ineffectiveness was caused by the lack of teachers’ attention to what was instructed by the tutors when designing HOTS questions in the first assisting program. Meanwhile, in the second assisting program, all activities of the teachers were effective consequently teacher’s ability in designing HOTS questions had also improved.

Reference

[1] Thompson T 2008 Mathematics teachers’ interpretation of high-order thinking in blooms taxonomy *International Electronic journal of Mathematics Education* 3 96
[2] Arends R I 2008 *Learning to Teach* (New York: Mc GrawHill Company)

[3] Harpster D L. A study of possible factors that influence the construction of teacher-made problems that assess higher-order thinking skills [Dissertation] Montana State University-Bozeman 1999

[4] Payne M 1986 *Social Care in The Community* (London: MacMillan)

[5] Wahyuni D E and Alimufi A 2015 Implementasi pembelajaran scientific approach dengan soal higher order thinking skill pada materi alat-alat optik kelas X di SMA Nahdatul Ulama 1 Gresik Jurnal Inovasi Pendidikan Fisika (JIPF) 4 32

[6] Rosnawati R 2009 *Enam Tahapan Aktivitas dalam Pembelajaran Matematika untuk Mendayagunakan Berpikir Tingkat Tinggi Siswa* (FMIPA UNY)

[7] Kusuma M D, Rosidin U, Abdurrahman and Suyatna A 2017 The development of higher order thinking skill (HOTS) instrument assessment in physics study Journal of Research and Method in Education (IOSR-JRME) 7 26

[8] Trimo 2013 Peningkatan aktivitas guru dan kemampuan mengolah nilai melalui pelatihan berbantuan microsoft excel pada guru-guru SDN 1 Magelung Jurnal Progress PKPI2 FAI Universitas Wahid Hasyim 1

[9] Mukhlis *Pendekatan Matematika Realistik untuk Materi Pokok Perbandingan di Kelas VII SMP Negeri Pallangga* [Tesis] tidak diterbitkan, Universitas Negeri Surabaya 2005

[10] Plomp T 2013 *Educational Design Research: an Introduction*, Ed T Plomp and N Nieven (Enschede: SLO) p 10

[11] Slameto 2010 *Belajar dan Faktor yang Mempengaruhinya* (Jakarta: PT Asdi Mahasatya)

[12] Sudjana D 1993 *Metoda dan teknik pembelajaran partisipatif* (Bandung: Nusantara Press)