Higher Order Thinking Skills and Students Ability to Use Technology on Integral Topic

Prihadi Kurniawan¹*, Arie Wahyuni²*, S. B. Waluya³, Adi Nur Cahyono⁴

¹UIN Walisongo Semarang, ²Universitas Ivet, ³Universitas Negeri Semarang

*kurniawan.prihadi@walisongo.ac.id

Abstract. This is a qualitative research that exposed the students’ higher order thinking skills (HOTS) and how they use the technology when solving a problem in calculus lecture, especially in integral topic. Autograph software is used as a new integrated technology on learning process. The samples used in this research are 8 mathematics students in second year of Mathematics Department, Ivet University. Students who are able to solve a problem and able to use their knowledge to a new situation, are the one who have high score in HOTS. How student use their knowledge to a new situation is based on how they use the autograph to construct their idea on integral basic studies.

1. Introduction

In this era, the world requires students to expand their cognition capacity. They need to develop their higher order thinking skills, such as critical system thinking, decision making, and problem solving [1]. Beyond the achievement of minimal competence, students also need to develop higher order thinking skills including critical literacy, critical numeracy, and cross-curricular competencies [2]. The creation of a technology enriched classroom environment appears to have had a positive effect on student acquisition of higher-order thinking skills [3]. Knowledge obtained through higher-order thinking processes is more easily transferable, so that students with a deep conceptual understanding of an idea will be much more likely to be able to apply that knowledge to solve new problems [4]. A study revealed the relationships between higher order thinking skills, cognitive density, and social presence in online learning. The study confirmed that high cognitive presence density did not guarantee the promotion of higher order thinking skills but that social presence was positively related to the quality of cognitive presence [5].

NCTM states that the learners have to study mathematics with understanding, it means learners have to develop their new knowledge actively from their own experience and previous knowledge [6]. To achieve those things, it is formulated in 5 general aims of mathematics learning, i.e: learn to communicate (mathematical communication), learn to reasons (mathematical reasoning), learn to solve the problem (mathematical problem solving), learn to connect an idea (mathematical connections), and forming the positive attitude towards mathematics (positive attitudes toward mathematics). These skills are normally called as Higher Order Thinking Skills (HOTS).

HOTS are the thinking skills activated when individuals encounter unfamiliar problems, uncertainties, questions, and dilemmas. In such situations, students cannot simply use a memorized solution but a combination of critical, logical, reflective, metacognitive, and creative thinking to develop a creative strategy to solve it [7]. This mental skill was initially determined based on Bloom’s Taxonomy which
categorized various levels of thinking, ranging from the lowest to the highest, namely knowledge (C1), understanding (C2), application (C3), analysis (C4), synthesis (C5) and evaluation (C6). Kusuma tells the dimensions of higher order thinking skills delivered by Bloom are as show in Table 1 [8]. Based on that dimension, Nugroho has examined and revealed the standard content of HOTS for mathematics as show in Table 2 [9].

| Table 1. The cognitive process dimension of HOTS |
|------------------------------------------------|
| The Knowledge Dimension | The Cognitive Process Dimension |  |
|--------------------------------|-----------------|-----------------|-----------------|
| Factual Knowledge | Making structure, classifying | Comparing, correlating | Joining |
| Conceptual Knowledge | Explain, analyze | Examine, interpret | Planning |
| Procedural Knowledge | Distinguish | Conclude, resume | Arrange formulate |
| Metacognitive Knowledge | Create, find | Make assess | Realization |

| Table 2. HOTS Descriptions and Indicators |
|------------------------------------------|
| Knowledge Dimension | Indicators | Descriptions |
|----------------------|------------|--------------|
| C4 Analysis | Differentiating | Student can differentiate between irrelevant and relevant parts or from important parts to insignificant parts of a given question. |
| | Organizing | Students can determine how a part of the element is suitable and can function together in determining the solution of a problem. |
| | Attributing | Students can determine the core of the relationship a question is given with the desired answer. |
| C5 Evaluate | Checking | Students can track inconsistencies or consistency of a process or result to support decision making on a given problem. |
| | Critiquing | Students can detect inconsistencies between the results and decisions in accordance with the procedures given problems and provide a description of what is considered true. |
| C6 Create | Producing | Students are given a description of a result and must create a product that matches the description given, students need to build they own ideas. |

If teachers purposely and persistently practice higher order thinking strategies for example, dealing in class with real-world problems, encouraging open-ended class discussions, and fostering inquiry-oriented experiments, there is a good chance for a consequent development of critical thinking capabilities [1]. The difficulty of generating ideas is a key factor in affecting the achievements of the students’ assignments. Students need to learn higher order thinking skills to address the difficulty in generating ideas [8]. With high level thinking, an individual will be able to use the new information or prior knowledge and manipulate information to obtain a reasonable response to new situations [8]. A well-designed program will drive learners towards greater levels of higher order thinking which helps them achieve the implicit goals set by the program itself and explicit goals personally set by the learners [9].

A research on presenting mathematics lectures from a Tablet PC adds new degrees of freedom that enhances interactive learning in the classroom. The ease with which various ICT Mathematics software programs can be integrated in the process of preparing electronic slides paves the way for quality presentations [10]. Computer-based attractive environments with visually compelling displays, together with facilities for interaction, can provide the setting for more dynamic, powerful experiences. These environments are filled with stimuli, which encourage rich constructions, by
students. The integration of constructivism and visualization can encourage the reformulation of conceptual structures and the development of higher order skills [11]. One of ICT Mathematics software programs that can be used in mathematics is Autograph. The use of Autograph technology improved the students’ overall achievements in the learning of area and volume by integration, including those who had not studied Additional Mathematics [12]. On an experimental study, students’ activity by using Dynamic Software Autograph during teaching and learning processes improved [13]. But, another study on Autograph implementation showed that the conventional strategy group had performed better than the Autograph group. Several factors that may lead to these findings are time constraints, lack of focus on the students’ part during the teaching and learning activity, teachers’ factor, and improved learning module for the students [14]. However, when ICT tools used, the teachers have been prepared to take risks and not every activity attempted has been met with complete success. One important dimension added by the teachers has been to relate the activities to the world familiar to their students [15].

2. Methodology
This research exposed how students uses new technology when solving some problems in mathematics depend on their HOTS. New technology used in this research is Dynamic Software Autograph.

The subjects used in this study were taken as a purposeful sample. Eight mathematics students in second year of Mathematics Department, Ivet University are chosen. Those eight students represent the three different categories (high, middle, and low). The categories are based on how the student solve some HOTS-problems in mathematics. They are 2 students from the high category, 3 students from middle categories, and 3 students from the low category. All of subject have never know and try Autograph before.

This study is a qualitative research. This research starts with assessing students by taking them a couple of mathematics HOTS-problems that focuses in assessing all indicators on each higher order dimension (C4: analysis, C5: evaluate, C6: create). Samples are chosen based from the test results. The test yields three categories: high, middle, and low score as show in Table 3.

| Categories | Mean Score, $\mu$ (%) |
|------------|-----------------------|
| High       | $\mu > 80$            |
| Middle     | $60 < \mu \leq 80$    |
| Low        | $\mu \leq 60$         |

After samples are chosen. They join calculus class, on integral discussion, that use Dynamic Software Autograph during teaching and learning process. Students need to use the Autograph to complete the task given during all the seasons. Participant observation is the most important part in this research. All of students’ activities, especially when they explore the Autograph, are recorded. Data is gathered in a natural way because they did not know that they were been observed.

In the end of each class, the samples do some in-depth interview. In this stage, open ended questions are used in order to get as many details as possible. Open ended questions allow for the informants to answer from their own frame of reference and express their thoughts more freely rather than being confined by the structure of pre-arranged questions [19]. Interview focuses in how they know and use Autograph as an integrated new ICT on education. All of the descriptive data (including quotations said by informants) is processed as a reflection to conclude how students use and develop their knowledge to a new situation.
3. Result and Discussions

Table 3 show the students’ category based on how the student solve some HOTS-problems in mathematics. They are 2 students from the high category, 3 students from middle categories, and 3 students from the low category. The category is pinned to the student in consonance with the mean of all indicators on each higher order dimensions, i.e. differentiating, organizing, attributing, checking, and critiquing.

| Category | Subject | Indicators |
|----------|---------|------------|
|          |         | C4-1 | C4-2 | C4-3 | C5-1 | C5-2 | C6 | μ    |
| High     | H1      | 80   | 75   | 95   | 85   | 90   | 85 | 85,0 |
|          | H2      | 80   | 75   | 95   | 80   | 85   | 82 | 82,8 |
| Middle   | M1      | 80   | 70   | 90   | 80   | 72   | 65 | 76,2 |
|          | M2      | 75   | 70   | 85   | 75   | 72   | 68 | 74,2 |
|          | M3      | 67   | 70   | 85   | 75   | 85   | 72 | 74,5 |
| Low      | L1      | 65   | 65   | 80   | 75   | 62   | 60 | 67,8 |
|          | L2      | 65   | 55   | 75   | 75   | 60   | 62 | 65,3 |
|          | L3      | 60   | 55   | 75   | 65   | 58   | 60 | 62,2 |

Note: C4-1: Differentiating  C4-3: Attributing  C5-2: Critiquing  C4-2: Organizing  C5-1: Checking  C6: Producing

The group first introduced to the Dynamic Software Autograph. One computer with Autograph installed on it is provided to each students. The students required to explore the software and its functions. Next, students introduced to the basic concept of integral followed by teaching and learning process using autograph. This phase involves instruction using the constructivist approach where students actively explore and discover concept of integral through software. During learning process, all eight students were observed. Table 4 shows the description guide for observation. How they use...
the autograph to construct their idea on integral studies is the main activity that highly recorded. Table 5 show about the emergence of each indicator on HOTS dimensions during learning activity.

Table 6 The Emergence of HOTS Dimensions

| Indicators           | Subject Number |
|----------------------|----------------|
|                      | H1  | H2  | M1  | M2  | M3  | L1  | L2  | L3  |
| C4 - Differentiating | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| C4 - Organizing      | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| C4 - Attributing     | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| C4 - Checking        | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| C5 - Critiquing      | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |
| C6 - Producing       | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   | ✓   |

After took some observations during learning process, the researcher did an interview to the subjects. The interview is focused on how they react and respond to Autograph as new technology that integrated in learning process. Table 6 summarizes the results of the interview with brief questions.

Table 7. Sort-Questions Recaps

| Questions                          | Subjects |
|------------------------------------|----------|
| 1. Is Autograph easy to handle?    | H1  H2  M1  M2  M3  L1  L2  L3  |
| 2. Was the integration of ICT to learning process fun? | y  y  y  y  y  y  n  y  y |
| 3. Did Autograph help lecturer explain the simple to complex concept? | y  y  y  y  y  n  y  n  n |
| 4. Do you get fascinated to this new application? | y  y  y  y  y  n  n  n  n |
| 5. Do you want to study more by using Autograph? | y  y  n  y  n  y  n  n  n |
| 6. Will you apply your new knowledge in using new technology on ICT to other subject? | y  y  n  n  y  n  n  n  n |
| 7. Is Autograph menu and tools simple? | y  y  y  y  y  y  y  y  y |
| 8. Do you fell clear when following lecturer directions? | y  y  y  n  n  n  n  n  n |

Note:  y: yes,  n: no

The recaps of the interview with open questions lead to an interesting result. Generally, students have a positive response to this new application. They said that lecturer looks easier to explain learning material. They get more interested because the presence of images and animations. Students did not suddenly get bored. But some time, some of them cannot find the suitable tools when do their assignment using Autograph. The students with high category of HOTS tend to do all aspect in higher dimensions well. With a simple directions and intro, they can explore their self to perform a command and pick a tool in Autograph. Before the lecturer ask to do something, those students in this category can look forward about what that supposed to do next. They can do step by step instruction using more than two commands and keep in mind when there is a mistake. Although Autograph is new for them, they can handle it perfectly. It means that the students with high category in HOTS can use their knowledge and experience to a new situation and build they own ideas about mathematical topics.

4. Conclusions

Students who are able to solve a problem and able to use their knowledge to a new situation, are the one who have high score in HOTS. How student use their knowledge to a new situation is based on how they use the autograph to construct their idea on integral basic studies. The next research should be prepared to answer a question like, “does Autograph help students’ to increasing their HOTS category?” or something like, “which is better, Autograph or other dynamic mathematical software, in order to increase students’ HOTS category?”. 
References

[1] B. Miri, B.-C. David and Z. Uri, "Purposely Teaching for the Promotion of Higher-order," Res Sci Educ, vol. 37, pp. 353-369, 2007.

[2] M. Forster, "Higher order thinking skills," Research Developments, vol. 11, no. 11, pp. 10-15, 2004.

[3] M. H. Hopson, R. L. Simms and G. A. Knezek, "Using a Technology-Enriched Environment to Improve Higher-Order Thinking Skills," Journal of Research on Technology in Education, vol. 34, no. 2, pp. 109-119, 2001.

[4] J. L. S. Ramos, B. B. Dolipas and B. B. Villamor, "Higher Order Thinking Skills and Academic Performance in Physics of College Students: A Regression Analysis," International Journal of Innovative Interdisciplinary Research, vol. 4, no. 1, pp. 48-60, 2013.

[5] S.-M. Lee, "The relationships between higher order thinking skills, cognitive density,," Internet and Higher Education, vol. 21, pp. 41-52, 2014.

[6] National Council of Teacher of Mathematics, Principles and standards for School, Reston: NCTM, 2000.

[7] F. J. King, L. Goodson and F. Rohani, Higher order thinking skills: Definitions, strategies, assessment, Tallahassee: Florida State University, 2011.

[8] M. D. Kusuma, "The Development of Higher Order Thinking Skill (Hots) Instrument," Journal of Research & Method in Education, pp. 26-31, 2017.

[9] R. A. Nugroho, Higher Order Thinking Skills, Jakarta: Gramedia, 2018.

[10] Y. M. Heong, J. M. Yunus, W. Othman, R. Hassan, T. T. Kiong and M. M. Mohamad, "The needs analysis of learning higher order thinking skills for generating ideas," Procedia - Social and Behavioral Sciences, vol. 59, no. 1, pp. 197-203, 2012.

[11] A. Lewis and D. Smith, "Defining Higher Order Thinking," Theory into Practice, vol. 32, no. 3, pp. 131-137, 1993.

[12] S. Stoney and R. Oliver, "Can Higher Order Thinking and Cognitive Engagement Be Enhanced with Multimedia?," Interactive Multimedia Electronic Journal of Computer-Enhance Learning, vol. 1, no. 2, 1999.

[13] W. Olivier, "Teaching Mathematics: Tablet PC Technology adds a new dimension," in The Mathematics Education into the 21st Century Project, Johor Bahru, 2005.

[14] D. C. Pountney and I. Malabar, "Using technology to integrate constructivism and visualisation in mathematics education," in Proceedings of the Second International Conference on the Teaching of Mathematics, Hersonissos, Crete, 2002.

[15] A. I. Moksin, M. Shahrrill, M. Anshari, M. Huda and K. A. Tengah, "The Learning of Integration in Calculus Using the Autograph Technology," Advanced Science Letters, vol. 24, no. 1, pp. 550-552, 2018.

[16] I. Karnasih and M. Sinaga, "Enhancing Mathematical Problem Solving and Mathematical Connection Through the Use of Dynamic Software Autograph in Cooperative Learning Think-Pair-Share," SAINSAB, vol. 7, no. 1, pp. 51-71, 2014.

[17] R. A. Tarmizi, A. S. M. Yunus, A. F. M. Ayub and K. A. Bakar, "Integration of Autograph Technology for Learning Algebra," European Journal of Social Sciences, vol. 9, no. 1, pp. 129-146, 2009.

[18] A. Oldknow, "ICT bringing mathematics to life and life to mathematics," The Electronic Journal of Mathematics and Technology, vol. 3, no. 2, pp. 137-148, 2009.

[19] R. C. Bogdan and S. K. Bilken, Qualitative Research for Education, London: : Pearson Eductir Inc., 2003.