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Cases of Thinking: Communication between Teacher and Students through Discovery Learning in Biology

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ABSTRACT

The research aims to identify patterns of communication between teacher and students when they construct knowledge. Identification was based on the category of thinking process in the dimension of knowledge of Bloom's Taxonomy. Research was a quasi-experimental pre-post test non-equivalent control group, in which the experiment class was treated with discovery learning, and the control was taught with the conventional method. The control class consisted of 31 students and the experiment class, 28 students. Both classes learned about the reproductive system. The conversations between the teacher and students were analysed based on Bloom's categories. Research results indicate that: 1) teacher and students have a relatively simiar distribution of thinking category; 2) discovery learning changes the distribution of thinking categories of teacher and students; 3) communication between teacher and students in discovery learning is clustered in concepts and facts; and 4) recalling (C1) and understanding (C2) were more dominant during the process of learning.

Keywords: Category, conceptual communication, discovery, factual, Taksonomy-Bloom, thinking

INTRODUCTION

Communication is a competence that is needed in the globalisation era (Binkley et al., 2012; Darling-Hammond, 2010; Dede, 2010; Kyllonen, 2012), primarily non-routine communication (Darling-Hammond, 2010). Non-routine communication is used in problem solving, and therefore communication becomes an important part in a learning process. Communication is a competence that requires more knowledge

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(Ananiadou & Claro, 2009). Communication, both oral and written, is used to achieve intended learning, but oral communication can better illustrate a thinking process exactly and be less influenced by other persons' considerations. Oliveira (2010) states that oral communication has practical social functions of acquiring and exploring students' experiences, as well as encouraging them to give meanings to transmitted experiences.

Oral communication in the classroom is the interaction between a teacher and students, and among students, in the form of statements and questions. The response, which is described as a statement or a question, is a reflection of communication of a learning approach design conducted during the learning process. Kawalkar and Vijapurkar (2013) stated that there is a relationship between students' cognitive scaffolding and the teacher's support to solve the problem, and therefore the oral communication that occurs in the classroom is a reflection of a cognitive process that blends in with the teacher's support. All types of oral communication in the form of questions and statements cover students' roles in creating the cognitive process (Cardoso, Eris, Badke-Scaub & Aurisicchio, 2014).

The cognitive process is divided into several categories, from recalling or remembering (C1) to creating (C6) in the knowledge dimensions of facts, concepts, procedures, and metacognitions (Anderson et al., 2001; Krathwohl, 2002), each of which has characteristics that visualise the cognitive process. The category of the cognitive process identified in various knowledge dimensions (Anderson et al., 2001) serves as a basis to identify and categorise the cognitive process of all oral communications that occur in the learning process.

Teacher's questions have a key role in building and developing students' communication skills that show the cognitive process primarily through inquiry learning (Chen, Hand, & Norton-Meier, 2016; Kawalkar & Vijapurkar, 2013). Discovery learning is closely related to inquiry learning (Chen et al., 2016), and they are often inseparable Goel & Joyner, 2015; Sutman, Schmuckler & Woodfiel, 2010). Hammer (1997) and Reynolds (2014) stated that discovery learning is a type of learning that gives experience to students in doing a project in a limited amount of time based on problems which are encountered during the learning process, resource utilisation and problem resolution. According to Reynolds (2014), discovery learning is a type of learning which aims to find a concept that is followed with curiosity, in which the teacher's questions in such learning have the same role as those in inquiry learning.

In general, teachers' questions are classified into four groups: questions to trigger ideas, moderator, trainer, and participant (Chen et al., 2016). All questions are used to trigger the cognitive process of the students (Kawalkar & Vijapurkar, 2013), and as a result, students will respond in the form of statements which are involved in the cognitive process as well. The category of cognitive process for teachers' and students' questions and statements in both conventional and discovery learning serves as a visualisation of cognitive scaffolding.

This research aims to identify the quality of students' thinking processes by analysing the communication process between a teacher and her students during the learning process. The questions to be answered were: 1) What is the impact of discovery learning on the thinking process of students? 2) What is the quality of teacher communication in discovery-based learning? and 3) How have the students' questions and statements changed during the learning process?

METHODS

A pre-post test control group, following the design by Drew, Hardman, and Hosp (2007), was employed in the present research. Samples were taken using purposive random sampling by selecting two classes for the control and treatment groups. The control group consisted of 31 students and there were 28 students in the latter group. Both groups were taught by the one biology teacher who is the assigned teacher for those classes. The former group applied conventional learning as daily practiced by the teacher, while the latter group used and implemented a discovery learning lesson plan, the syntax of which was proposed by Veermans (2003). Prior to the experiment, permission was granted by the Educational Board of Surakarta Regency, school management, and role teacher, as well as students. The teacher was also trained to acquire the syntax of discovery learning before the lesson got started.

The implementation of discovery learning was measured using Veerman's syntax, which was adjusted to the given materials. The process of learning was monitored and adjusted to the curriculum design following Forbes and Davis (2010). Data of communication comprising the teacher's and students' questions and statements were obtained from direct observation and recording the conversations which occurred during the learning process. The teacher's and students' questions and statements were analysed based on the categories of Bloom's knowledge dimensions of facts (F), concepts (K), procedures (P), and metacognitions (M), and cognitive levels C1, C2, C3, C4, C5, and C6 (Anderson et al., 2001). Based on this categorisation, a number of 24 categories were obtained: FC1, FC2, FC3, FC4, FC5, FC6, KC1, KC2, KC3, KC4, KC5, KC6, PC1, PC2, PC3, PC4, PC5, PC6, MC1, MC2, MC3, MC4, MC5, and MC6. The quantity in each category shows the number of individuals involved in delivering a statement or a question. Each question and statement contained in the category of knowledge dimension has dissimilar qualities of thinking.

The analysis of the quality and quantity of the teacher's and students' questions and statements indicates their communication competence during the implementation of discovery learning. According to Veermans (2003), the implementation of discovery learning comprises several stages, including: orientation, hypothesis generation, hypothesis testing, conclusion, and regulation. The quantity and quality of the teacher's and students' questions and statements were computed in each subtopic among five subtopics which were discussed, namely: 1) the structure of the reproductive organs; 2) the formation process of sex cells or gametes; 3) ovulation, menstruation, fertilisation, gestation and childbirth; 4) breast milk and family planning; and 5) disorders and diseases in the human reproductive system.

The teacher's and students' questions and statements prior to the implementation of discovery learning were used as pretest data, while data obtained after the implementation of discovery learning on the fifth topic (disorders and diseases in the human reproductive system) were used as posttest data. The percentage calculation was based on the teacher's and students' questions and statements when discussing the subtopics. The analysis results were categorised and accumulated in each category of the cognitive process on knowledge dimensions.

The communication between the teacher and students in the learning process consists of: 1) teacher's statements (TS) and questions (TQ); and 2) students' statements (SS) and questions (SQ), both calculated and analysed in control and treatment groups.

RESULTS

The classifications of the analysis results were separated into statements and questions. The distribution of teacher's and learners' statements by grouping the categories of knowledge dimensions, before and after the treatment using discovery learning, is seen to be dominated by the knowledge dimensions of facts and concepts as in Figure 1.

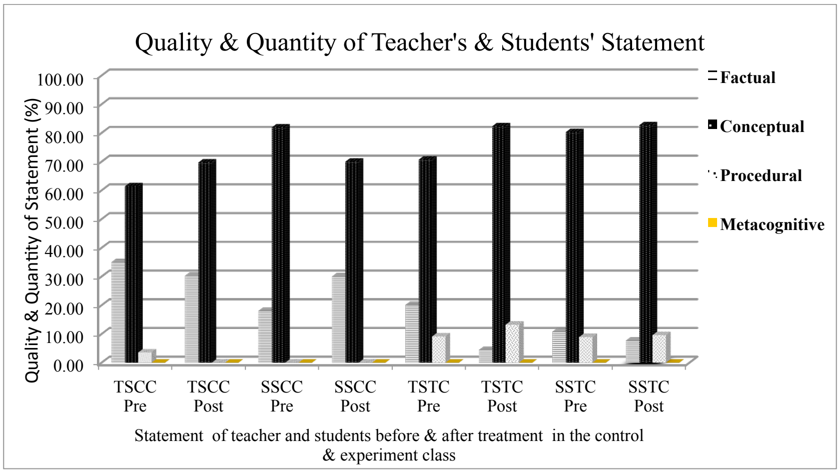

Figure 1. Distribution of teacher's and students' statements after treatment in the treatment and control class

Figure 1 shows that communication in the form of statements of teachers and learners is dominated by concepts and facts. In reality, this shows that the process of constructing knowledge does not involve many scientific procedures to concept building. The analysis of thinking processes by Bloom's Taxonomy of teacher's and learners' statements in the knowledge dimensions of facts, concepts, procedures and metacognition in detail is shown in Table 1.

Table 1
Percentage of thinking process in teacher's and students' statements in the knowledge dimensions

Dimension of knowledge	Thinking Process	TSCC Pre	TSCC Post	SSCC Pre	SSCC Post	TSTC Pre	TSTC Post	SSTC Pre	SSTC Post
Factual	C1	31.43	15.60	11.11	16.00	18.90	1.47	9.86	1.44
	C2	2.86	14.68	6.94	12.00	1.22	2.94	0.00	4.33
	C3	0.71	0.00	0.00	2.00	0.00	0,00	0.47	0.96
	C4	0.00	0,00	0,00	0,00	0.00	0.00	0.00	0,00
	C5	0.00	0.00	0.00	0.00	0,00	0.00	0.47	0.96
	C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Conceptual	C1	50.00	51.38	26.39	30.00	57.32	60.29	46.95	46.15
	C2	11.43	15.60	55.56	34.00	13.41	19.85	32.39	31.73
	C3	0.00	1.83	0.00	4.00	0.00	0.74	0.94	0.48
	C4	0.00	0.00	0.00	2.00	0.00	1.47	0.00	3.37
	C5	0.00	0.92	0.00	0.00	0.00	0.00	0.00	0.96
	C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Procedural	C1	3.57	0.00	0.00	0.00	7.93	12.50	8.92	8.17
	C2	0.00	0.00	0.00	0.00	1.22	0.74	0.00	1.44
	C3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metacognitive	C1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note:
TSCC Pre : Teacher statement precontrol class
TSCC Post : Teacher statement post control class
SSCC Pre : Student statement precontrol class
SSCC Post : Student statement post control class
TSTC Pre : Teacher statement pretreatment class
TSTC Post : Teacher statement post treatment class
SSTC Pre : Student statement pretreatment class
SSTC Post : Student statement post treatment class

Table 1 shows the percentage of teacher's and learners' quality of thinking identified from the statements during the learning process, generally accumulating in C1 and C2 for the factual and conceptual dimensions that Khan and Inamullah (2011) found, including in the categorical low-thinking process. The analysis of thinking processes is also conducted on the questions of teacher and learners as part of communication during discovery learning, as shown in Figure 2.

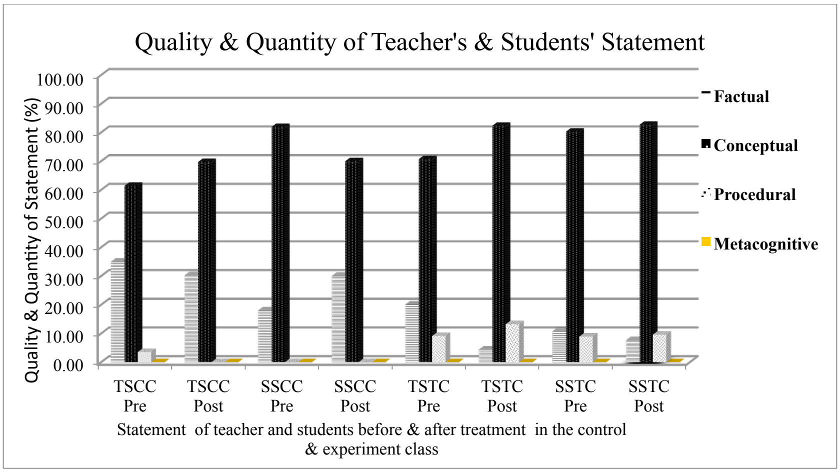

Figure 2. Distribution of teacher's and students' questions in the dimensions of knowledge and categories of thinking process

Note:

TQCC Pre :	Teacher question pre control class	TQTC Pre :	Teacher question pre treatment class
TQCC Post:	Teacher question post control class	TQTC Post:	Teacher question post treatment class
SQCC Pre :	Student question pre control class	SQTC Pre :	Student question pre treatment class
SQCC Post:	Student question post control class	SQTC Post:	Student question post treatment class

Communication in questions of teachers and learners in the dimensions of knowledge and the thinking processes is figured out in Figure 2. The distribution of teacher's and learners' questions is still dominated by knowledge of facts and concepts, but in the treatment class, teacher and students also achieved the dimensions of procedures. Categories of thought processes of teacher's and students' questions in more detail on the dimensions of facts, concepts, procedures and metacognition are shown in Table 2.

Table 2
Percentage of thinking process of teachers' and students' questions in the knowledge dimensions

Dimension of knowledge	Thinking Process	TQCC Pre	TQCC Post	SQCC Pre	SQCC Post	TQTC Pre	TQTC Post	SQTC Pre	SQTC Post
Factual	C1	28.33	18.75	78.57	0.00	23.88	0.94	1.18	0.00
	C2	3.33	12,50	0.00	13.33	1.49	4.72	0.00	0.00
	C3	0.00	4,17	0.00	0.00	0.00	0.00	0.00	0.00
	C4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C5	0.00	0.00	7.14	0.00	0.00	0.00	0.00	1.06
	C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0,00
Conceptual	C1	48.33	35.42	0.00	13.33	47.01	50.94	22.35	8.51
	C2	20.00	22.92	14.29	53.33	23.88	33.96	57.65	64.89
	C3	0.00	4.17	0.00	0.00	0.00	0.94	1.18	1.06
	C4	0.00	2.08	0.00	13.33	0.00	2.83	4.71	15.96
	C5	0.00	0.00	0.00	6.67	0.00	0.00	0.00	3.19
	C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Procedural	C1	0.00	0.00	0.00	0.00	3.73	5.66	10.59	2.13
	C2	0.00	0.00	0.00	0.00	0.00	0.00	2.35	3.19
	C3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metacognitive	C1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	C6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note:
TQCC Pre : Teacher question precontrol class
TQCC Post : Teacher question post control class
SQCC Pre : Student question precontrol class
SQCC Post : Student question post control class
TQTC Pre Teacher question pretreatment class
TQTC Post Teacher question post treatment class
SQTC Pre Student question pretreatment class
SQTC Post Student question post treatment class

Table 2 shows that the questions of teacher and learners clustered on the thinking processes C1, C2, C3, and C5 on the knowledge dimensions of facts and concepts, but on C1 and C2 for the knowledge dimensions of procedures in the treatment class. The knowledge dimensions of metacognition for the statements and questions of teachers and students are zero.

DISCUSSION

Discovery learning, in general, exerts an influence on communication in the form of teacher's and students' statements and questions. Saab (2005) concludes that there is a significant relationship among discovery learning, specifically the stages of hypothesis formulation, design research, and conclusion drawing. The stages of hypothesis, design research and conclusions require understanding and argumentation that are identified from the statements and questions of teachers and learners; this is supported by the research of Chen et al. (2016) which showed that teacher's questions have the opportunity to increase the thinking and improve the participation of learners. Kawalkar and Vijapurkar (2013) stated that all questions are inducers to start learners thinking.

The present research indicates that communication in the form of questions has a bigger change than statements. The indications of communication that occurred in the discovery class indicate that questions are a more thoughtful part of learning than statements. Research carried out by Rahmawati, Widoretno, Suciati Sudarisman, Ramli, and Ariyanto (2016) revealed that discovery learning enables the improvement of students' questions.

The difference between the percentage change of statements and that of questions in discovery learning exists due to: 1) questions, the essence of the cognitive process (Chen et al., 2016; Kawalkar & Vijapurkar, 2013; Oliveira, 2010). Discovery learning is a type of learning which requires the cognitive process more than conventional learning (Oliveira, 2010). A statement is an answer which is already provided in a book, or is based on an experience that an individual perceives; 2) discovery learning is defined as a type of learning which constructs knowledge according to phenomena presented based on Veermans's (2003) stages of learning. The stages require more information which start with questions. Teachers and learners practice asking each other questions to understand the facts, concepts and procedures, so the assumption is that using discovery learning increases the quantity and quality of questions from both teacher and learners.

The aggregate distribution pattern on the knowledge dimension of concept points out that concept serves as the easiest component to be transferred in learning, as shown by what has occurred so far. The noncontextual transfer of knowledge often happens in conventional learning. Another reason is the concept construction requires a process of thinking of greater quantity. The mastery of concepts is a teacher's attempt to transfer knowledge that begins with facts. The use of facts based on those obtained from natural phenomena or events is an attempt to make contextual learning.

The knowledge is orally transmitted and students only listen and clarify their knowledge on a certain topic in their book. It is logical and is in accordance with its analysis results that cognitive processes of communication in the form of teacher's and students' statements and questions identified includes recalling or remembering (C1) and understanding (C2), whereas in fact they are considered as lower order thinking (Turiman, Omar, Daud, & Osman, 2012). All conditions which occur in the process of one-way knowledge transfer are inversely proportional to the constructivist philosophy which demands facts or phenomena for knowledge construction (Gunckel, 2010; Pedaste et al., 2015).

According to Zohar and Barzilai (2015), education allows students to gain Higher Order Thinking Skills (HOTS). Being identical to general education goals, discovery learning aims to gain HOTS, comprising: using (C3), analysing (C4), evaluating (C5), and creating (C6) teacher's and students' statements and questions, and therefore, this method presents a collective attempt to improve the cognitive process. In fact, only communication in the form of questions was identified in C3, C4 and C5. Therefore, it can be assumed that discovery learning enables teacher and students to change the cognitive process through curiosity by asking questions. The solutions and answers manifested in statements, however, were not visualised in similar cognitive processes. The imbalance of the change in cognitive processes based on the analysis of the teacher's and students' statements and questions creates a research gap to reveal further research on teachers' competencies and supporting factors in intertwining effective communication.

Statements and questions accumulated in the knowledge dimension of concepts imply that understanding a concept is important to develop deeper comprehension since it serves as a representation of connection (Boles, Goncher, & Jayalath, 2015). Understanding of the knowledge dimension of concepts without that of supporting facts does not belong to the expected learning outcome. Gunckel (2010) proposes the Experiences-Patterns-Explanations (EPE) model of science, and states that a meaningful concept is obtained from many experiences, facts, and phenomena. The expected learning outcome is not limited to the understanding of the concept, but rather to the implementation of the concept in daily life. Analysing and creating something, which is related to problem solving, is a challenge for the learning outcome to fulfil. This confirms Kyllonen's (2012) statement that the need for effective, efficient, and meaningful communication is an important skills requirement for the 21st century world of work.

The results of the analysis of the cognitive process using Bloom's Taxonomy on communication in the form of the teacher's and students' statements and questions were found in questions which belong to conceptual knowledge with cognitive processes of C4 (analysing), and C5 (evaluating). The cognitive processes of C4 and C5 are included as HOTS (Khan & Inamullah, 2011; Turiman et al., 2012). In statements, however, similar cognitive processes were not found, or they were even found in a lower category. The fact that questions convey higher cognitive processes triggers an attempt to gain HOTS through discovery learning.

Limbach and Waugh (2010) and Oliveira (2010) stated that one effort a teacher should make to develop HOTS is that he should teach using convergent questions which require answers from C1, C2, and C3, as well as employing divergent questions which require answers from C4, C5, and C6. Unfortunately, in the present case, the teacher has not optimally posed the divergent questions, and therefore, communication in the form of statements does not change the distribution of the cognitive process as well as the knowledge dimension, even by implementing discovery learning.

CONCLUSION

Discovery learning changes the teacher's and students' communication, particularly that in the form of questions. However, divergent questions were not mastered by the teacher, and therefore, the identified statements did not show the high level of the cognitive process. The change in the cognitive process on questions was identified to contain facts, concepts, and procedures with the cognitive processes of C1, C2, C3, C4 and C5, while statements of change were found in the dimensions of facts and concepts with the cognitive processes of C1 and C2.

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