

The Development of the Checklists for Students' Interaction with Others in Learning Mathematics

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1. Introduction

It is reported that one of the issues to focus on in today's socio-cultural society with technology, is to identify how the advent of new media, like the computer, influences our social and psychological processes as human beings (Wertsch, 1993). It is necessary to perform research on various phenomena of educational speech within a technological environment to develop educational theories and concepts, which can be adapted in the math classroom. We assume that students will well be prepared for responsible citizenship in the future through experiences gained in the classroom, designed with the educational theories and concepts.

Through the collaborative learning of small groups, we can observe their thinking processes in detail, analyze educational communications in the process of developing knowledge, and investigate their meta-cognitive activities, in order to find how much technology contributes to students learning of mathematics. If we are able to find various functions of mathematical language and a user's intent of a certain form of

language in the interaction with technology, the desirable and specific ways of using technology could be recommended, including other aspects of language. NCTM(2000) suggested that communication can support students' learning of new mathematical concepts as they act out a situation, draw, use objects, give verbal accounts and explanations, use diagrams, write and use mathematical symbols (p. 61).

To perform the research, we need to develop a special instrument that is able to find the aspects of using language and to identify practical features of communication. However, there is little research dealing with instruments of this nature, and even less relating mathematics to linguistic communication. Therefore, this research developed checklists to make it possible to analyze educational communication indicating students constructing knowledge, to detect dynamic aspects of the discourse in mathematical learning, and to identify the role of the teachers language in students learning.

-Research questions-

The purpose of this study was to devise checklists to identify characteristics of linguistic interaction as students developed mathematical

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knowledge using technology. The research questions were as follows:

1. What are the linguistic components indicating student's constructing knowledge?
2. What are the components comprising dynamic interactions between students, and between students and a teacher?
3. What components are included in a teacher's instructional statement with students?

II. Review of literature

Linguistic interaction in social constructivism

One of the prominent theories in recent educational trends is Vygotsky's social constructivism. It discusses characteristics of knowledge, its development and the function of speech, and provides an alternative way of thinking. Vygotsky explains that human mental functions are mediated by 'signs' of which one is speech. Furthermore, each subject is an active participant in the interaction with the world as well as in introducing the mediator to a subject's mental process. To explain the higher forms of human behavior, we must uncover the means by which man learns to organize and direct his behavior. The main question about the process of concept formation or about any goal-directed activity is the question of the means by which the operation is accomplished.

All the higher psychic functions are mediated processes, and signs are basic means used to master and direct them. The mediating sign is

incorporated in their structure as an indispensable, indeed the central, part of the total process. In concept formation, that sign is the word, which at first plays the role of means in forming a concept and later becomes its symbols (Vygotsky, 1962 p.56).

Speech plays several important roles in the interaction. In pursuit of appropriating the higher level of mental function, the speech of the less advanced shows such functions as exploring an alternative stage of mental function, as well as requesting and manipulating the assistance of the more advanced. It is noteworthy that the function of speech of the more advanced is not a direct instruction, but a tool to assist, to motivate, to guide the activity and to organize the necessary tasks for the less advanced. Meanwhile, this intermental mediation of speech is depicted to be different from the intramental mediation of speech. At present, the followers of Vygotsky are currently exploring the various functions, characteristics, and the pragmatics phenomena of the speech of the intermental plan.

Concept formation is the result of a complex activity in which all the basic intellectual functions take part. The process cannot, however, be reduced to association, attention, imaginary, inference, or determining tendencies. They are all indispensable, but they are insufficient without the use of the sign, or word, as the means by which we direct our mental operations, control their course, and channel them toward the solution of the problem confronting us (Vygotsky, 1962, p58).

It must be clear that words also fulfill an important, though different, function in the

various stages of thinking in complexes (Vygotsky, 1962, p.78).

As Lemke(1988) pointed out, a specific speech genre must be learned from each subject in school. Speech genres from all different disciplines in the classroom uniquely blend certain forms of discourses with the content specific domain.

The mastery of every subject is a mastery of the semantic patterns of some particular thematic formations and of the genre structures of the subject and their uses (Lemke, 1988, P.88).

What creates enormous problems for students is that the speech genre specific to a certain subject is not explicitly taught or even talked about. One consequence is that the different aspects of the speech genre of mathematics in schools discussion, argumentation, debate, monologue and so on - have to be explicitly treated in the classroom(Seeger, 1998, p. 97).

III. Method

The diversity of qualitative research perspectives employed in mathematics education research present a sufficient range to elicit controversy. Recent commentaries address the conflicting and complementary perspectives that cognitive science, socio-cultural theory, and constructivism provide for studying students learning within the broad paradigm of qualitative research. To address the research questions, a case study design(Yin, 1994; Stake, 1995) was used because of the designs unique strength in dealing with a full variety of evidence-notes,

interviews and observations-beyond what might be available in other studies.

1. Subjects

The criteria for participation in this study were: (a) volunteers, (b) the person who could take an active part in the classroom, and (c) the person who had already acquired algorithm knowledge for performing the four basic mathematical operations (addition, subtraction, multiplication, and division). Their grades were distributed in above 30% of achievement of peer students and they had various home backgrounds, but all the students who participated in this study had some difficulty in learning mathematics. The subject group of participants is as follows:

Tangu (S1): He was greatly concerned about the graphing calculator and tried to work hard although he had a poor understanding of mathematics.

Mingu (S2): He was cheerful but he did not like to think profoundly.

Sangu (S3): He had not spoken much during class but took a positive attitude in this study.

2. Procedure

The pilot study was conducted with two groups of eight 11th graders voluntarily participating in the study during the second semester of 2001. During the pilot study students worked on fraction functions and trigonometry in a paper-pencil environment where technology was not provided. The purpose of the pilot study was to find the degree of flexibility and availability

of using the checklists roughly outlined from previous research, most of which did not relate to mathematics. The main instruction using a graphing calculator was performed by the 11th grade boys in groups of three or four students from the department of electronics in a vocational high school in the areas of fraction functions (3 lessons) and trigonometry (2 lessons) in the first semester of 2002. To collect data, one group was selected. The main instruction seemed to offer the researcher a second chance to modify the checklists according to the purpose of the study.

The data were collected in various forms: audio-tapes and video-tapes, the researchers notes on observations, and students sketches from the lessons. All tapes collected during the instruction were transcribed into written words at the day of recording. Based on transcripts, the checklists were created. However, since the checklists were not constructed by the intercoder agreement from different perspectives of researchers, the checklists underwent repetitive correction through constant comparison, during analysis of the data. Finally, the researcher made some changes on the checklists by the data earned from students interactions in a technology environment in addition to the results from the pilot study.

IV. The results

To gain various information about educational communication performed in classrooms, we need to find as many cases as possible and interpret them based on data. Before doing that, it is necessary to develop the instruments that

detect the characteristics and functions in the processes of students communication. The reason that the study analyzed students linguistic interactions with others is to find what components support students learning in mathematics. Then, teachers in classrooms may find the ways of enhancing students learning with awareness of their use of language based on this study. To observe the processes that take place in the classrooms, there should be focuses on developing methods that enable them to investigate the processes of students interactions, depending on semantic aspects rather than physical aspects of words.

The first draft of checklists was designed from previous research (Alexopolou & Driver, 1996; Greenleaf & Freedman, 1993; Hogan, 1999; Javis. & Robinson. 1997; King, 1991; Sprod, 1997; Palinscar, Brown, & Campione, 1993; Wegerif & Mercer, 1997; Cobb, Wood, & Yackel, 1993) about students linguistic interaction. Through the pilot study and the main study, the checklists had been modified and more specified, based on the components of mathematical knowledge. In the main study, the researcher tried to reinforce the categories of the linguistic components that were shown more often in using technology. The checklists may be adapted to various research on mathematical discourses.

(1) Knowledge construction statement

In the early stage of students learning, it was hard to see students speak out on what they thought about mathematics properties, so the researcher needed to depend on what she

observed of students behaviors. However, as time passed, students interactions became more active and their verbal description could start to be detected. To find what aspects of linguistic interactions indicated in students learning, the researcher needed to specify the components of the knowledge construction with technology as they constructed their mathematical concepts.

The checklists for the processes of constructing students knowledge is called a Knowledge Construction Statement, detailing all discourses on mathematical content in a classroom whether the technology was used or not. The KCS is divided into Reflective Statement and Instrument Operational Statement. The former gets divided into four areas: Conceptual Statement, Meta- cognitive Statement, Questioning, and Teacher Statement. The Teacher Statement here accounts for only the frequency of teachers statement. Finding more specific components of the teachers statement would be done in the category of the Teachers Instructional Statement. The Instrument Operational Statement, in contrast to the Reflective Statement, includes the students expression only dealing with operating the instrument, a graphing calculator. The Instrument Operational Statement was sorted apart from the students constructing knowledge or learning something mentally. That is, the intent of sorting the instrument operational statement apart from the reflective statement was to differentiate statements for the use of technology itself in the analysis of causes for the growth of linguistic interactions. Thus, the Reflective Statement dealt with the components related to students constructing knowledge or their exploration to develop knowledge.

A. Conceptual statement

The category of the conceptual statement includes all statements that presented in solving mathematical tasks such as students own thoughts about mathematical content, and facts and conjectures observed on the graphing calculator. It was found that there were seven components: Opinion presentation of concretely exploring (C1), Recall of content knowledge previously acquired (C2), Information propose relating to the tasks to be solved (C3), Analytic statement of discussing the tasks (C4), Extensible statement of high-order contents or concepts (C5), Execution statement of procedures or processes for solving the tasks (C6), and lastly, Elaborating on or compensating his/her own or others statements (C7). The following protocol indicates the evidence of these seven components in students constructing knowledge.

(C1) S: Just input something. Input a given number into X , now fill each element of the table? What happen next?

(C2) S: Didn't we learn this already? What did we do, starting at 1?

(C3) S: No, well-it keeps getting smaller from 1.

(C4) S: The width gets wider, doesn't it?

Since this is 3 here, and 3 there.

(C5) S: maximum 3, minimum 3, yes! The maximum gets increased. The difference is their maximum differs.

(C6) S: Substitute a number on the graph, and its reciprocal being -2. Then, we put a dot here.

(C7) S: It is moving to the right side-. Oh-it is a parallel movement.

B. Meta-cognitive statement

Students do behave strategically in solving problems and are able to direct and monitor their own learning. The meta-cognitive statement described in the transcripts includes the components consisting of the following statements: What should be solved in the problem?; The difficulty in solving problems as to whether it can be solved or not; the reflection based on outside criteria that the processes and results should meet; the evaluation of the degree of his/her own or others understanding; and the control in comparing activities between the task situation and the existing concepts. In general, the meta-cognitive statements dealt with thinking that what I think of, and whether I can solve the task or not.

Confirming a problem and predicting the result of solving the problem (M1), are the statements, which enable students to internalize the problem and to reason how much they know about the problem and whether they can solve the problem or not. Evaluating the degree of the difficulty the task itself has (M2) describes the familiarity or resistance students have with the problem, and difficulty in the process of exploring concepts and strategies the problem requires. The Reflection of the processes and results of the problem (M3) is concerned about whether the procedure of solving the problem is performed in a correct way according to relevant knowledge and strategies with a tool, and how correctly the rules and the formula are used in the task. The Evaluating on the degree of understanding (M4)

indicates how much they communicate or share their knowledge in interactions. The Control of behavior (M5) in activities of discerning similarities and differences between the given task situation and the existing concepts requires the in-depth thinking process that connects all relevant facts and finds new methods and contents. Finally, the Belief (M6) deals with the statements of convincing his/her ability or expressing his/her thought about the lack in performing the task. The examples for each component are followed as the protocol shown below.

(M1) S: one hundredth? Are you drawing a graph? This graph will probably be like the one I pictured (presenting the fraction function with the graph of a linear function). Is this what we learned in middle school?

(M2) S: How can we draw these? It is not that. Either?

(M3) S1: (Pointing out the graph S2 drew), hey, is this right? Weren't the X-axis and the Y-axis switched? No, they weren't!

(M4) S: They get smaller? If they get smaller, then it becomes a minus?

(M5) S2: See! Look at this. (keeping moving right with the trace), it gets smaller, but never become a minus as it approaches to 0.

(M6) S2: Oh-this is perfect! Math is starting to sound like fun. Cool! Isn't it?

C. Questioning

It is necessary for educators to recognize the importance of the role of questions in the light of the fact that all discourses in a teaching and learning situation consist of questions and explanations between students and between a teacher and students. The questions help students to produce mental operation, activities the students by themselves don't or can't do. This interaction plays the role of guidance in the processes of the discourse and reinforces students cognitive activities in social contexts by helping both students and a teacher to recognize useful questions for solving a problem. Also, this interaction can be activated to a larger extent by proposing information that enhances students understanding. Therefore, the appropriate questioning leads valid explanations and the reorganization of knowledge. Recognizing that analysis of questioning refers to the analysis of the processes that develop communication, so we naturally have an opportunity to identify the components of effective linguistic interaction. The questions are largely divided into Strategic questions, Elaborating questions, and Non-elaborating questions. The Strategic questions include Planning questions(Q1), Checking questions(Q2), and Evaluating questions(Q3), relating to a task. The Elaborating questions(Q4) are not enough to be the strategic questions, but the questions that give concrete helps and are relevant to the procedures students need to use. The Non-elaborating questions(Q5) in contrast to the elaborating questions dealt with asking ambiguous things, not helps for specific strategies and

procedures.

D. Teacher statement

The instruction that Vygotsky suggested is called assisted discovery, which describes that the learning students achieve should be able to be done for themselves, but the learning students themselves can not achieve should be provided with teachers appropriate help. So, the role of the teacher should be considered in the interaction with students for students constructing concepts. In this category, only the frequency of the teachers participation in the interaction was counted. The checklist for teachers more specific interaction is discussed later in the category of Teacher Instructional Statement.

E. Instrument operational statement

The statements mentioned in the knowledge construction statements using a calculator are divided into two categories: the Reflection statements (R) and the Instrument operational statements (I). The researcher perceived that there were the statements that didn't affect students learning, even though they activated the students participation in communication. Thus, the researcher excluded these statements from analysis of linguistic interactions with others since these statements were only used to manipulate a calculator and had no direct relation with mathematical contents.

(An example) S: Tell me how to push (pushing many keys)? I push this. Next, which one?

(2) Social interaction statement

In this category, we talk about the checklist that enables us to collect holistic information and dynamic aspects of the linguistic interaction and to find a difficulty in the linguistic interaction. First, the leading statements mean that a learner, regardless of whether it is right or not, plays a main role and reaches the result of a task by him/herself. The turn-taking statements are useful to know if the interaction properly occurs, and are classified into relevant turn and irrelevant turn. The relevant turn consists of the communication initiation for one topic and the appropriate response to it. On the other hand, the irrelevant turn indicates that students who start the communication respond irrelevantly to a given topic. That is, it includes useless talks irrelevant to a task and dialogues that have nothing to do with the task. It refers to such cases as he/she misunderstands a task and changes the direction of solving the task with intent. The Structure entails that a learner leads and controls the situation even in a restricted situation. The situation was called structuralization where students lead to the problem solving out of a pause or the crisis of breaking off a discourse. The Control Stress stands for the statements from behaviors related to interaction to minimize psychological tension and anxiety. In the middle of the learning processes, students try to resume their linguistic interaction by controlling the stress

whose psychological loads often result in the discontinuance of the discourse and irrelevant response.

(They were drawing graphs using a graphing calculator)

(L) S: This is different from the ones before.

Look, look, look at this. It goes up that way. Aha-movement, this is called a movement. So to speak, this moves as many as 3 to the X-axis and as many as 2 to the Y-axis. Yes! This is a cinch. Lets go to the next problem. Isnt it over yet?

S3: What is this? Did you say, Write the difference? The same is the answer. It's the same.

S1: Are we finished, now?

(S) S2: Owah. They look the same, but their starting points are different. They are not the same. There is something. Dont we think that their starting points being different is most probably the right answer?

S1: Is it a fraction, again? I hate fractions. How can we draw all these at once? We can even draw one of them...

S2: Can t we draw with this?

(C) S1: Miss Koh, may I use a calculator? She said, yes. Then its a piece of cake. Hey, dude, input the formula on it.

Knowledge Construction Statement(KCS)	
CONCEPTUAL STATEMENT(C) _____Exploring statement (C1) _____Recall statement (C2) _____Information statement (C3) _____Analytic statement(C4) _____Extensible statement (C5) _____Execution statement (C6) _____Elaborating statement (C7)	METACONCEPTUAL STATEMENT(M) _____Confirming & Predicting (M1) _____Degree of Difficulty in the task (M2) _____Reflection (M3) _____Evaluating(M4) _____Control behavior(M5) _____Belief (M6)
QUESTIONING(Q) _____Strategic question _____Planning (Q1) _____Checking (Q2) _____Evaluating (Q3)	_____Non-strategic question _____Elaborating (Q4) _____Non-elaborating (Q5)
TEACHER STATEMENT (T)	
INSTRUMENT OPERATIONAL STATEMENT (T)	
Social Interaction Statement (SIS)	
_____Leading statement (L) _____Relevant turn (R) _____Irrelevant Turn (I) _____Structuralization (S) _____Control stress (C)	

Table 1: The components of KCS & SIS

(3) Teacher's instructional statement on the role of teachers language in instructional activities is encountered. This study created the checklists accepting the constructivists view required in responsive teaching and reciprocal teaching, in order to fulfill the teachers role as a guidance helping students to construct their know-

It is meaningless to claim that one can transmit knowledge to others directly using language, especially in developing conceptual understanding. Thus, the need for a revised view

ledge. Through the pilot study, it included teachers linguistic aspects that cant help existing in discourses as well as simplifying the statements that were too specific to have meaning. In this category, in order to specialize pedagogic functions in teachers linguistic aspects, the teachers communication was divided into seven components: Firstly, Prescribing (D1) for identifying knowledge that students have already understood as statements eliciting students knowledge, and Drawing (D2) for sharing knowledge by eliciting it. Secondly, Directing answering (A1) for providing answers directly to what they ask, Re-questioning (A2) to repeat a question or to be silent for facilitating students thinking, and Clue (A3) for connecting knowledge as a form of passive response. Thirdly, Says Elaborately (M1) and Rephrase using signs (M2) for demon-

strating an exemplary linguistic expression. Fourthly, Guiding (E1) and Bridging (E2) for extending students thinking and developing discourses. Fifthly, Confirming knowledge (C1) and Confirming error cause (C2) for reminding of what they work on in the middle of solving a problem in case of being unclear without confirming the task or what they already understand. Sixthly, as encouragement and considerate requesting, Requesting elaboration (R1) of linguistic or non-linguistic performance for advancing from implicit statements to explicit statements, and Requesting progress (R2) for being necessary to mediate in case of pausing or giving and taking inappropriate opinions. Lastly, Self-confidence (S) for cheering and encouraging when they give up solving the problem, showing the lack of confidence in communication with the teacher.

Teacher's Instructional Statement(TIS)	
DIAGNOSIS(D)	EXTENSION(E)
_____Catching (D1)	_____Guide (E1)
_____Eliciting (D2)	_____Bridge (E2)
ANSWER (A)	CONFIRMING(C)
_____Direct (A1)	_____Knowledge (C1)
_____Re-questioning (A2)	_____Error cause (C2)
_____Clue (A3)	
MODEL(M)	REQUESTING (R)
_____Says Elaborately (M1)	_____Elaboration (R1)
_____Rephrase using signs (M2)	_____Progress (R2)
	COGNITIVE STRUCTURING(S)
	_____Explanation(S1)
	_____Self-confidence(S2)

Table3: The components of TIS

V. Conclusion

In this study, the checklists were devised, based on the components of students' linguistic interactions in the learning environment using small-group discussions and technology. In addition to empirical analysis of the pilot study, the discourse patterns of the main study were video-and-audio-taped, transcribed and analyzed. Finally, the checklists modified by the results from the main study are composed of three categories of statements in their learning: Knowledge construction statements, Social interaction statements, and Teacher instructional statements. We admit that some components are overlapped and interrelated to each other because of the diversity and flexibility of language.

As Susan (1988) pointed out, we need to consciously work harder to uncover the mathematical reality that each individual student creates, and to bear in mind that this reality can be revealed to us only through the mediation of language and supposedly shared meanings. And intellectual process that occurs on the threshold of adolescence appears to be the use of the word as a means of concept formation (Vygotsky, 1962).

However, analyzing linguistic interaction has a methodological problem across all research projects that focus on observing classroom processes because the standard checklists already devised deal with linguistic structures only, and are not used to depict educational or cognitive processes in students learning. These traditional devices allowed the researcher to conduct the superficial classification in a simple form rather

than with the thorough analysis on the contexts in classrooms. But the significance of the checklists developed in this study suggests that social-interactive structures in discourses and students cognitive processes in classrooms be investigated with in-depth analysis, using the checklists: the Knowledge construction statements enable us to perform semantic analysis about students cognitive development, the function and the structure through language interrelated as well as to comprehend how we can regulate student behaviors by using technology. The social interaction statements can study the total processes of students constructing knowledge in all its dynamic phases where a teacher plays the decisive role of guiding students learning. Lastly, the teacher's instructional statements can suggest ways the teacher uses his/her language to promote all the processes to students advanced knowledge.

Using the results from this study, students interaction protocols will be investigated and analyzed for finding characteristics of linguistic interaction within an interactive-technology environment to make a discourse very effective. This study implies the possibility of using language anew in the context of education and establishes the educational use of language as a valid domain of inquiry in mathematics. A lot of research related to the role of language use in mathematical learning can be conducted in the area of students knowledge development.

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수학 학습에서 학생의 상호작용 분석을 위한 도구 개발

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정보화시대를 맞아 어느 때보다도 활발히 전 교과에 걸쳐 학생의 의사소통의 능력을 향상하기 위한 다양한 방법이 모색되고 있다. 학교현장의 수학교육자는 수학교수-학습에서 어떤 상호작용이 일어났는지, 특히 다루기 쉬운 도구로써 계산기가 주어졌을 때 어떻게 학생의 지식 발달이 언어적 상호작용에서 이루어지는지를 알아야 한다. 본 연구는 이러한 학생의 상호작용을 분석할 때 필요한 분석도구를 개발하

는 것이다. 예비연구와 본 연구를 통해 언어적 상호작용의 구성요소가 세 영역, 즉, 지식 구성 진술, 사회적 상호작용 진술, 그리고 교사의 교육어 진술에서 개발되었다. 본 연구에서 개발한 자료를 이용하여 특히 학생의 지식 구성 발달에 따른 상호작용의 구성요소의 특징을 파악하고 이에 필요한 언어적 상호작용의 역할과 활성화 방안을 모색하는 연구가 가능하다.

Index Words: Learning Mathematics, Social Constructivism, Linguistic Interaction, Knowledge Construction Statement, Social Interaction Statement, Teacher's Instructional Statement, Technology Environment.
수학학습, 사회적 구성주의, 언어적 상호작용. 지식구성 진술, 사회적 상호작용진술, 교사 교수학적 진술, 기술공학 환경