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Department ogf Teacher Education
Faculty of Education
University of Zimbabwe
P O Box MP 167
Mt Pleasant
Harare
Zimbabwe

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ABOUT THE CONTRIBUTOR

Cribert Munetsi is a Lecturer in the Department of Teacher Education while he teaches Mathematics, Mathematics Education and Research methods and Evaluation.

INNOVATING ENVIRONMENTS OF CONSTRUCTIVIST THINKING

CRIBERT MUNETSI

UNIVERSITY OF ZIMBABWE

DEPARTMENT OF TEACHER EDUCATION

ABSTRACT

"The task of education--- becomes a task of first informing models of the students' conceptual constructs and then generating hypotheses as to how the students could be given the opportunity to modify their structures so that they lead to mathematical actions that might be considered compatible with the teacher's expectations and goals. (Von Glazer-feld, 1990, p.34).

The purpose of this article is twofold. I intend first to describe four beliefs about teaching, the classroom, and the children which provide a basis for innovating a constructionist environment in which to learn mathematics. I will then draw illustrative examples from the classrooms on which I have extensive data to show some of the results of providing such environments.

Theoretical Considerations Innovating a Constructionist Environment: four necessary, underlying tends of belief

What are the qualities of the intentions of a teacher who attempts to innovate or produce a constructivist environment for mathematical teaching and understanding? I observe four tenet. of belief as critical:

(a) Although a teacher may have the intention to move students towards particular mathematics learning goals, he will be well aware that such progress may not be achieved by some of the students and may not be achieved as expected by others. Regardless of the environment, children build their own knowledge and mathematical understanding. In displaying their own understanding, children may be seen to form images or notice mathematical properties which are false or even incompatible in the eyes of the teacher. Yet that is the understanding with which the student is showing at that moment and therefore the understanding with which the teacher must work. This tenet suggests that under constructionist principles a teacher must be continually re-renovating the environment, not only in the light of individual student constructions but also for the class as a whole. There can be no intention to plan a teaching sequence and then simply apply that plan. The teacher must be constantly reappraising the learning taking place within the environment as it evolves.

(b) Innovating an environment or providing opportunities for children to modify their mathematical understanding, the teacher will act upon the belief that there are different pathways to similar "mathematical understanding".

This belief in different routes to mathematical understanding entails a realisation that each student comes to his or her current state of understanding through a unique pattern of engagement in the various kinds of activities offered. (Again I must stress that I am not necessarily talking about physical activities). There is no unique or even best path for growth in understanding. As a direct result of this, there is also no particular form or sequence of construction which can be positively associated with growth in understanding in a constructivist environment.

(c) The teacher will be aware that different people will hold different mathematical understandings. From this a number of implications follow. The teacher cannot think that his or her own understanding, the understanding of a given mathematician, the understanding underlying the writing of particular texts and materials, the students' understanding will all be the same for any particular mathematical topic. Indeed the students themselves will all possess their own understandings which will be inherently different from one another. Thus, innovating a "constructionist environment" meaning that the teacher will be oriented to account for this variation. This inter-student difference is not simply a matter of rate or style in reaching a given understanding of a given mathematical topic. There is no such thing as, for example, an "understanding of fractions" to eventually bypassed onto, or even gained by students. An understanding of a topic is not an acquisition. Understanding is an ongoing process which is by nature unique to that student. Holding this tenet implies that the teacher believes in and, just as importantly, acts on this difference in understanding.

(d) The teacher will know that for any topic there are different levels of understanding, but that there are never achieved "one and for all". This tenet is, as were the proceedings too, concerned with the growth of a student's mathematical understanding. Here that are interested in the teacher's interactions in terms of allowing for this growth. I see mathematical understanding as entailing the continual organisation of self-built knowledge structures. This research and theorising over the past four years have focused on mathematical understanding as an ongoing, dynamic process. Although it is beyond the limitations of this article to describe my theory of understanding in detail, this has been done else (Pirie and Kieren, 1989). In short, my theory poses the notion that there are eight potential levels in the growth of mathematical understanding in namely, promotive knowing, image making, image having, property noticing, formalizing, observing, structuring and inventory. I see each of these layers of understanding as embeddedding, but allowing access to, all previous layers. I see growth in a person's mathematical understanding with respect to a topic as a back-and-fourth movement between activities at different levels. This I term "folding back". At certain stages, such as the transition from the image-oriented first three layers to the level of formalising, understanding is said to have crossed a "don't need" boundary. The implication of these boundaries is that, although one can easily fold back to previous levels, such activity is no longer necessary to function mathematically in a particular topic. Growth in understanding is thus a dynamic, organising and re-organizing process.

As with the previous three tenets, this fourth statement has implications for how teachers reach to what they observe in the classrooms.

They will not only be aware that students will display different ways, but will not expect that different students will exhibit different kinds of understanding in the face of these same mathematical tasks. Possibly the most important result of this and the previous tenet, however, is the need to be aware that although two students may appear to exhibit the same understanding this may not be the case. The implication of this is that simply examining what a student does in the face of a mathematical task is not enough. If a teacher is to really observe the kind of understanding shown by a student, he must prompt students to justify what they say or do and thus reveal their thinking and logic. In order to expose different levels of understanding, tacks need to be used which allow for varying levels of response.

Not only should a teacher allow for and validate differences in levels of understanding between students, but he must also function in the awareness of the different levels of understanding within any one individual students. Human beings, unlike computers, understand things at many levels at once. (Minsky, 1986). A teacher cannot think, "Oh John is now at formalizing level of understanding fractions, and hence will use formal algorithms from now on to handle tasks".

My theory of the growth of understanding referred to above suggests that a teacher must be aware that a student will fold back to less formal, less sophisticated actions as part of the normal growth process. In fact, a teacher who is trying to innovate a constructionist environment might deliberately try to invoke folding back to such previous level action as a means of promoting growth.

In summary, this section, so far has been arguing that a constructivist environment for mathematics learning is not a product of a particular programme of classroom or individual activity. Such an environment is produced by a teacher through a set of constructivist beliefs in actions. These include the belief that there is no mathematical understanding "out there" to be acquired or achieved by students. Students act to develop their own unique understanding. In observing, and forming models of students' understanding, and in designing opportunities for growth of understanding, the teacher will take cognisance of the different pathways to such understandings which may be taken. Because a teacher is consciously responding to the diversity of student constructions, any of the variety of instructional acts might be appropriate.

However careful the preparation, the teacher who is innovating a constructivist environment will know that, since it is each student's system of knowing and acting which determines what that student will achieve, his goals for a student or class may not be achieved as intended.

METHODOLOGY AND DISCUSSIONS: MATHEMATICAL ACTIVITY IN A CONSTRUCTIVIST ENVIRONMENT

Suppose one observed students in a classroom where the teacher created/innovated an environment based on the constructivist beliefs outlined above. What would one see? Would the mathematical understanding actions of the students support these beliefs? I intend now to consider the above questions with reference to data collected during detailed observations taken in classes of 8 years olds and 12 year olds working on the topic of fractions. Audio recording of verbal contributions of the students and teachers were made, records of the on going student activities were kept, and the written work of all students was available for the sake of simplicity of this article, I have elected to consider classes, both of whom were engaged in building understandings of the rational numbers. I wish to make it clear that I do not intend that either my remarks and analyses with respect to constructivist theory of the growth of mathematical understanding upon which some of the analyses are based should be seen as stemming solely from consideration of the mathematical content of this particular topic.

Because I am arguing that a constructivist environment is the ongoing creation or innovation of the teacher, in each of the two episodes offered below, a description of the constructivist intentions of the teacher is given. This is followed by a record of the incident and an analysis in the light of the tenets developed above.

Episode 1

Background Three eight year old children were using one metre paper strips known as 'dragons", folded into halves, fourths, eighths, and sixteenths to measure things. The teacher intervened in their dialogue with the intention of offering appropriate language to aid their growth of understanding through communication using conventional terminology.

Record In this episode, the students had marked off on the wall the height of one of the girls and were trying to find its exact measurement. Kudzai tried using a whole string and one fourth but this was less than the marked height, and Chipo said, "Let's get out an eighth dragon". When adding an eighth proved too big, they tried adding a sixteenth instead. This was still too long. Nyasha then said, "It's a half a sixteenth more". Chipo responded, "a thirty-two".

At this point, the teacher, who was observing all of this, interjected, "It's called a thirty-second".

Nyasha persisted, "She is one and a fourth and half of a sixteenth [units tall]". Chipo, quietly, "a thirty twoth". (She followed this with a chuckle, quite clearly indicating her preference for her own language logic!).

Analysis: In this measurement situation, while Kudzai does not know what to do when a simple combination of measures does not match the height, both Chipo and Nyasha exhibit the understanding that one can find a measure by combining further smaller units. In fact, Nyasha expresses the measurement not in terms of quantities but in terms of a problem solving process: "half of a sixteenth".

As a teacher frequently does, this teacher offers "correct" language for the amount. In this case, however, Nyasha and Chipo act in a way that the teacher did not anticipate - both reject his proffered suggestion but for quite different reasons. Nyasha wished to describe a process and did not want to use a quantity name. Chipo, while wishing to use a quantity name, persisted in using a name which fitted in with the logical system which she could see in use: fourth, eighth, sixteenth---.

This is a brief but clear example of the children's intentions determining their, in this case verbal, actions. They had different purposes for the understanding they were at that moment trying to construct, different both from each other and from the teacher. While the teacher offered correct and useful information, he could not assume that the children would use it.

Episode 2

Background In the several days prior to this episode these 12 year old students had been working with image making for the equivalence of fractions, addition, and subtraction using continuous rectangular units in the contexts of pizzas which were cut into halves, thirds, fourths, sixths, eighths, twelfths and so on. Students had been asked to write down five things they know about fractional numbers. Some responses which show image, held and properties noticed were:
- Fractions make amounts of things. Two fractions would look different but be the same amount, (John).

- Each fraction has unlimited equal fractions (Peter)

- Any fraction can go on forever. For example ½, 2/4, 3/6, 4/8, 5/10, 6/12, 7/14, 8/16, 9/18, 10/20 11/22 --- (Joe)

Record. The teacher's intention in the following episode was to review orally the responses to review work in which the students had been asked to generate fractions of an hour from given numbers of minutes.

- Teacher: What about 15 minutes? (John)
John: Two eighths.
T: (A little surprised by the answer) Two eighths? Two eights of what?

J: Two eighths of (hessitation) a pizza.
T: Well, we are dealing with time here
J: Oh Yeah! Two eighths of an hour.
T: Any other fraction of an hour which tells us about 15 minutes? Bonnie? Bonnie one-fourth hour.
T: Good. Let's start a list, (writing) Two eights, one fourth --- others
Sarah: Three 12ths.
T: Why is that?

Taurai: Well 5, 5 and 5 are 15. They are one 12th so three 12ths of an hour.
T: Yes, We could see that on the clock.- in five-minute pieces. One, two, three 12ths. (writes 3/12) Any other?
Peter: Four 16ths
T: (adding 4/16 to the list) other?
Daniel: How about seven 28ths.
(The list now reads: 2/8; 1/4; 3/12; 4/16; 7/28).
Joe: (Interrupting) what a minute. Some of those fractions are less equivalent than others. (Pause) No, no they're all equivalent to one fourth.
No, Joe. Go! Don't stop! that's a good idea. See: two 8ths and one 4th, and one 4th and three 12ths - they're really equivalent. But two 8ths and three 12ths aren't as equivalent and three 12ths and seven 28ths, they're hardly equivalent at all!

Analysis: This episode illustrates many of the features of a constructivist environment. First, it shows that in an environment were different individual understandings are expected, even the act of checking up on a simple exercise can provide a rich interactive mathematical environment. I see the validity of the teacher's assuming different understandings yet, what is evident is that these different individual understandings are compatible and contribute to the growth of understanding within the class. Sarah's statement reveals that her understanding of this situation entails observing aspects of a physical image. The offering of 7/28 by Daniel, on the other hand, shows him using a property of constructing equivalent fractions that he has noticed - namely, multiplying the numerator and demoninator of 1/4 by 7. The creation of the list of equivalent fractions allowed the teacher to observe the different related understandings held by various children. Because students expected to have to explain or validate their answers, this activity also allowed students to participate based on their own mental structures.

The striking aspect of this episode, though, is the way that this simple list of equivalent fractions in response to a routine exercise also triggers the expression of an original, and rather different, understanding. Peter, who has previously exhibited formalised understanding with respect to equivalence - he expects any fractions to be part of an infinite set of equivalent fractions - is now prompted to fold back and notice a new property - "less equivalent than". Although Peter appears to retreat to his more formal concept of equivalence, his remarks invoked Joe to also fold back and he starts a discussion on this new noticed property.

In a constructivist environment, the assumption of different understandings and different levels of understanding leads a teacher not merely to look for simple answers to routine questions, but to allow for and seek and even be surprised by the different mathematical understandings shown by students.

Conclusion

In this article I have attempted to portray a constructivist environment in the mathematics classroom, not in terms of the use of specific materials, micro-worlds, or teaching styles but as an innovation or creation arising out of the teacher's ongoing process of acting from a constructivist belief in the nature of mathematical learning. Such a teacher knows that there is no external mathematical understanding to be acquired or even attained by students. Each person's mathematical understanding is unique. Indeed, since I believe that all knowledge is personally constructed and organised, students in any environment will construct understanding in some . What I am interested in is the innovation or creation by a teacher on environment which is consciously based on optimising the opportunities for the construction of mathematical understanding. For this reason, such a teacher is free to choose from the many different kinds of instructional acts available to her, knowing what they can contribute to students construction of mathematics.

I focused on four tenets of a constructivist stand point which I felt could be investigated in the classroom and analyzed by data from this perspective. Any act of the teacher or feature of the environment will not necessarily lead to a student's constructing or displaying the mathematical understanding expected by the teacher. Furthermore, students exhibiting similar mathematical behaviours will infact have different understandings since there are different levels of understanding within any one topic and these can be reached by students through different pathways.

So, what happens when a teachers acts to create or innovate an environment in this manner? The episodes analyzed above appear to validate my choice of foci. In these constructivist environments, children did indeed show individual understandings of the mathematics being taught. In the two episodes, despite the intended goals of the teacher, students are free to construct mathematics based on their own structures and ideas, and even in this environment, students can still arrive at incomplete or profound understandings unanticipated by the teacher. In the same episodes, I saw different students construct and show different, but compatible and coherent, understandings of fractions.

While in a constructivist environment, the knowledge and understanding built by students is based on each one's own intuitive knowing, and the teacher needs to observe carefully the understanding displayed by his students and provide opportunities for validation, together with provocative and invocative challenges for them. As shown in episode 1, however, it is the student's response to the situation rather than the nature of the situation which determines the student's pathway to understanding. I have tried to argue and illustrate that the teacher's continuing constructive act of "creating or producing or innovating a constructivist environment" can have observable consequences in the growth of knowing and mathematical understanding by students. I have tried also to show some of the ongoing demands of such an environment for the teacher and the richness and texture of such an environment for the students.

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