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Students' perceptions about the relevance of mathematics to other school subjects

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Abstract: Ethiopian pre-university students' perception about the relevance of mathematics was examined within a framework of cultural historical activity theory. In particular, Engeström's expanded mediational triangle was used. A mixed approach of both qualitative and quantitative methods was employed. Group interview was undertaken. A total of 24 students were interviewed in groups of three. The interview was supported by classroom observation. The data analysis gave rise to diverse characterizations of students' perceptions. The identified characterizations were used to construct items of a survey questionnaire. In both the quantitative and qualitative approaches, 4 students' categories were used for sampling: gender, grade level, stream and level of achievement. No statistically significant disparities in the distributions of perceptions were found across the students' categories. These characterizations of perceptions are widely held by students. The results also indicate that perceptions are motivational factor for engaging in mathematics. The implications of the results for the teaching of mathematics and for the teacher education program of mathematics and other school subjects are set out.

Keywords: mathematics, motivation, other school subjects, perception, relevance.

Introduction

The issue of relating mathematics to other school subjects (OSS) has been a focus of attention in mathematics education research for many years. There are studies which examined the use of mathematics in other subjects (e.g. Rojano, 2002; Michelsen & Sriraman, 2009). But little has been done on the associated perception. From my experience as mathematics teacher at primary, secondary and tertiary level the application of mathematics to OSS was using word problems. The use of word problems to show the practical application of mathematics has been discussed in mathematics education literature (e.g. Greer, Verschaffel & De Corte, 2002). They explain that word problems are important to expose for students that the mathematical concepts have application, and to enable them use these concepts in practical situations. Greer et al did not consider about using word problems to relate mathematics to OSS. There are studies on the issue of relevance which focus on the real-life applications of mathematics and science school subjects (e.g. Darby, 2008). Darby studied about the ways teachers are making mathematics and science relevant to students' lives. Though some of the teachers in Darby's study teach both mathematics and science, there is no evidence in this study that relate the relevance of mathematics to the OSS.

Connecting mathematics to OSS enhances students' interests and motivates them towards learning (Michelsen & Sriraman, 2009). Interest is a motivational factor for students engaging in mathematics (ibid). Michelsen & Sriraman (2009) reported that their review of previous studies revealed that students' interests decrease as they go up in grade levels particularly in upper secondary levels. Michelsen and Sriraman viewed the students' point of view through questionnaires and interviews. In addition to exposing the students' perceptions about the relevance of mathematics to the OSS, my study further exposes some attempts made to connect the subjects in the mathematics classroom, particularly using word problems and their influences on the students' perceptions of relevance. The students' motivation is influenced by their expectations of success, the cost that their engagement might incur, the value that the student attaches to the mathematical task and/or to mathematics and its utility in achieving some goal (Eccles & Wigfield, 2002). The studies on the connection between

mathematics and OSS at upper secondary level are scarce. Studies about the relevance of mathematics to the other school subjects are particularly very scarce in contexts where there is limited access to modern technology such as in the Ethiopian context.

The Ethiopian context and the school system

I start this section by giving a historical context to the introduction of modern education in Ethiopia. It is intended to expose the context to the reader and enable to understand interpretations. A consideration of such issues might also help to relate the findings in this study to other settings. The theory that I adopt, cultural historical activity theory, also places emphasis on the historical context of the study. There has been traditional education associated with religion before modern education was introduced (Wagaw, 1979). The traditional education associated with the two major religions in Ethiopia (Orthodox Christian and Islam) were widely recognized in the country. There has been traditional education associated with the Ethiopian Orthodox Church. The church dates back to the 4th century. Islam is also introduced in Ethiopia during its early years and the traditional education has a strong base. Still some parents send their children to the traditional schools. Some Orthodox Christian parents send their children to let them have basic skills of reading the Geez letters and numerals (an old language which is now used in the church only). The Muslim parents also send their children to schools in Mosque and Madrassa to let their children learn the Quran in Arabic. Modern education was introduced in Ethiopia at the turn of the 20th century (Hoot, Szente & Mebratu, 2004). In 1908 the first modern school comprising primary and secondary levels was opened in Addis Ababa, which was named after the Emperor (Minilik II) who ruled the country from 1889–1913 (Hoot, Szente & Mebratu, 2004). Additionally, new technologies were introduced in his reign. Rail transport was established between Addis Ababa and Port of Djibouti (Hoot, Szente, & Mebratu, 2004); telecommunication and postal system were introduced. This gives a historical context to the learning of mathematics and the students' perception about the relevance of mathematics to them.

The students' who participated in this study are learning in a much more advanced technological context as compared to the situation that prevailed when modern education was introduced a hundred years ago. Yet, Ethiopia is a very poor country. The students have an impoverished life. They have limited access to modern technology, particularly outside the school. 12th grade students have internet access at the school. The internet center has 25 computers 20 of which work effectively. Students are provided with training on how to browse for about 2 hours. Since the internet service is not stable, the training was not given regularly. For example, the training was not offered in the academic year 2009/2010. Internet service is open every day after school finishes and during lunch break for a total of 2 and half hours. There are internet cafes outside the school. But, in general, the students are not likely to afford to pay for using it. The limited resource available for them seems to make the students be dependent on the school and the teachers for acquiring the knowledge they require.

The Ethiopian schools system is structured in three levels: preschool, primary and secondary. Primary level includes from first grade till eighth grade. The normal starting age for first grade is six to seven years of age. The media of instruction at primary level are the national language and the other local vernaculars. The official language of Ethiopia is Amharic. In primary schools; that is up until 8th grade, students learn through their mother tongues for selected languages (Ministry of Education, 1994). In the capital, Addis Ababa, the school language in public primary schools is the Amharic language. At the primary level students learn English as one school subject (Ministry of Education, 1994). At the secondary level, that is, in ninth grade, students begin to learn many of the subjects including mathematics through the medium of English language. However, students do not normally communicate in English. It is usually used only in the classrooms. In Ethiopian public secondary schools it is a regular practice of the teachers to explain concepts in Amharic or other local vernaculars so that the student can grasp the concepts being taught. This practice contravenes the language policy of the schools.

The secondary level has two cycles: 1st cycle includes 9th and 10th grades, and 2nd cycle includes 11th and 12th grades. The 2nd cycle is referred to as preparatory school. The students must succeed in a national examination in order to join *preparatory* schools. Among the students who could not

succeed, some (who have a better score) will join the technical and vocational schools. The students who succeed in this national examination will attend *preparatory* school for 2 years. When they go to the university, they do not attend freshman programs. Rather, they are directly enrolled in their respective fields of study. The students in this group are recognized as the elite of their age group in accordance with the Ethiopian school system. They have demonstrated their capabilities through succeeding in two national examinations taken at the end of 8th and 10th grades. They will attend preparatory school and they will take the 3rd national examination, in which they are hopeful of succeeding because of the high pass rate. The school had 2818 and 2968 students, in 2009/2010 and 2010/2011 academic years, respectively. The number of male and female students is balanced. The number of natural science students is more than the number of social science students. Based on a recent policy the schools enforce that 70% of the students should be enrolled in natural science stream. All the students in the respective streams attend to the same subjects and topics. That is, there are no elective subjects within the streams, and taking mathematics is mandatory.

My study reports about Ethiopia students' perception about the relevance of mathematics to OSS. The participants are pre-university students. This report is part of a project whose preliminary results have been reported earlier (Gebremichael, 2013; Gebremichael, Goodchild & Nygaard, 2011). The research question addressed in this report is "what is the students' perception about the relevance of mathematics to OSS?" The paper is structured as follows. The theoretical framework; the methodological issues and results are presented in this order. The results section is includes subsections. Then, the conclusion is presented.

Theoretical framework

In this study I employ cultural historical activity (CHAT), particularly, Engeström's triangle which models activity as an object-oriented and mediated by tools and signs (including community, division of labor and rules) (Cole & Engeström, 1993). The students in this study participate in the activity of schooling. Their motive appears to be joining the university. The object of the activity of schooling consists of their motive, their goal of learning school subjects and their future goal which might involve mathematics. In order to realize their activity of schooling, the students take various actions such as attending classes, studying school subjects, doing homework, engaging in group work, etc (cf. Leont'ev, 1979). These actions are directed towards the goal of learning mathematics and OSS. In this process the students make choices among these actions and take decisions, where the school subjects might appear to be competing with each other.

The students are participating in the historically situated activity of schooling. There has been the activity of schooling before they enrolled into school (and *preparatory* school). They have been participating in the activity of schooling before they joined the *preparatory* school. They exploit their prior experiences and they are mentored by others, including their teachers. They are also mentored by parents and siblings while participating in other activities such as family life. They might assume a different role in the different activities (see Gebremichael, 2013). In these activities, the community, the division of labor, and the rules mediate their perceptions and also form the structure in which their perceptions are formed (cf. Roth, Tobin, Elmesky, Carambo, McKnight & Beers, 2004). Participants also experience tensions within and between the parts that form the structure (ibid). In my study following Vygotsky (1978) perception is understood as attaching of meaning and making sense of mathematical experience. 'Relevance' is understood as connection.

Methodological issues

My study is situated in the interpretivist paradigm, because I am focusing on meaning; the meaning that students attach to their learning of mathematics in relation to its relevance to the OSS (cf. Denzin & Lincoln, 2000). The focus in this study is on meaning and the prevalence of this meaning among the students. Thus, the research method employed involves both qualitative and quantitative methods. A mixed approach was employed, in which interviews; classroom observation and questionnaire are used to collect data in a school where I taught more than a decade ago. In both the interviews and

completion of questionnaire, the categories of students used for sampling were gender, streams, grade levels and levels of achievements. The students are roughly 16 to 18 years of age.

Pilot study was undertaken in the academic year 2009/2010. Data were collected using interviews. One classroom observation was undertaken in each of the participants' classes prior to the interview session. In particular, the classroom observation was used to probe during the interview. Three students of the same gender and from the same class who are high, medium and low achievers were interviewed together. A total of 24 students participated in the interviews. They were selected by four mathematics teachers, from their respective classes. The department head selected the four teachers based on their better experiences with the students and students' academic standings. They have firsthand responsibilities of students. The themes that emerged in the analysis of the pilot data were further analyzed using Engeström model, which further exposed students' perceptions (see Gebremichael, et al., 2011).

The results from the pilot data were used to construct the items of a questionnaire. The data collection using the questionnaire took place a year after the pilot data was collected (i.e., in the academic year 2010/2011). The questionnaire contained 29 items. It was translated into Amharic because the teachers were skeptical about the students' ability to understand and write responses in English language. The students who participated in completion of the questionnaire were randomly selected using lottery method. 335 students completed the questionnaire. Using exploratory factor analysis six underlying dimensions were identified. This paper reports on the items, which cluster together and form the dimension, "Mathematics is a tool in OSS". Further analysis of the data was undertaken using bar graphs, Mann-Whitney test and Kruskal-Wallis test. The results from the data analysis are presented in the next section.

Result

The results from the quantitative and qualitative data analysis are set out in this section. I start with presenting the theme that resulted from the qualitative data analysis. This will be followed by the analysis of the data arising from the questionnaire. The data arising from the questionnaire is presented in two subtopics, which are about the proportions of students' responses and the distributions of students' perceptions across categories of students.

Students' perceptions about use of mathematics in other school subjects

Students perceive that mathematics is relevant to OSS. This is revealed in their explanations during our discussions about the possible applications of mathematics in OSS.

Mekia:	Mathematics is useful for physics. … In chemistry we have mathematics
Makida:	It is not said directly. But indirectly, it has application in physics, etc. e.g. we use logarithm in chemistry, limit & derivative in physics. There could also be in biology. We used to think that math is just playing with numbers but it has application in others.
Hayal:	Science without mathematics? I don't believe that.
Meada:	We use differential formula, and derivative in physics in 12th but it was before we learned it in mathematics. … Quadratic in physics
Ahadu:	Logarithm is used in chemistry
Habtu:	Physics involves number e.g. vector. … Those [mathematical concepts] we are learning now are rarely used
Beza:	Logarithm, we learnt, is applied in bacterial growth; so it is used in biology.

Fikru: In 7th or 8th our teacher said 'mathematics is the king of all subjects'. … It has use in chemistry; rector scale in geography; it is related with all OSS.

Meseret: We are social, we don't use much calculation. This makes us not to pay much attention to mathematics, I think. … OSS are to be learnt by heart; I take break with mathematics. I don't allot special time for it. … [Mathematics] is a mother tongue. … In economics there is slope. We learnt it in 7th or 8th [grade mathematics]. We didn't know then that it has this use

Debesh: There is calculation in Geography, Business; not the [subject] mathematics but the calculation in these subjects is useful. … I think there are subjects which are related to mathematics. Those subjects have societal values. Thus, your knowledge of mathematics will help you for dealing with those subjects.

The students appear to be able to know the usefulness of mathematics in OSS from their experiences in mathematics or from their experiences in the OSS. The school rules, which enforce the topics to be covered in the school subjects and the sequences of concepts across subjects, mediate Maeda's perception. The mismatch between the learning of the mathematics concept and the learning of its application in physics seems to limit the opportunity of appreciating the usefulness of mathematics. Meseret's perception is also mediated by the school rules which enforce the topics to be covered in specific streams and subjects. Her motivation for engaging in mathematics is low. She chooses to be engaged in other school subjects. She does not allot time for engaging in mathematics. When she feels like she needs a break, she gets engaged in studying mathematics. There appears to be motivation associated with perception. When Meseret remembers of some applications of mathematics in the school subjects she attends to she tends to appreciate the relevance of mathematics. The limited utility of the mathematics concepts she attends to appear to direct her attention to perceive that mathematics has little relevance to the other school subjects. The teacher also mediates the students' perception of relevance (see Fikru's story). The students have high regard for the mathematics teacher. The students tend to justify their argument by referring to the teacher. One can find many such references to what their teacher has told.

During one of my classroom observations in Debesh's, Meseret's and Beza's class (11th grade social science classroom), I have seen the mathematics teacher discussing about the use of logarithms in chemistry as well as in measuring rector scale. I did not hear the teacher telling that these are concepts in chemistry or OSS; it is my understanding of my experience with these concepts. The mathematics teacher was providing an example about Richter scale and pH value in a lesson about logarithmic function. The participants from this class also mentioned it as an application in chemistry. Such exploiting of the relationships between school subjects in the teaching of mathematics is very important. That is, it might help in creating practical examples to interest the students as they perceive that the OSS are closer to real-life than mathematics (see Debesh's story; cf. Michelsen & Sriraman, 2009).

The students also explain about their experiencing of mathematics word problems. In our discussion about possible ways of presenting the applications of mathematics in the mathematics classroom, the students gave their explanations.

Meada: [Applications of mathematics] appear as word problems. … Word problems are difficult to understand. But it is our attitude; our experience with mathematics is that it is playing with numbers.

In our discussion about their preferences of some kinds of mathematics, some students revealed their emotional relationships with some aspects of mathematics. The following students tell stories about their emotional relationships with mathematics.

Debesh: I like all but word problems are tricky. Use difficult words … or they are difficult to understand.

Abebe: I like word problems, because it involves critical thinking and analyzing. … it has to be related to our society, things that we know and experience in our lives. Not in some other society; the names when related to our situation then we do it with interest. When it talks about some world we don't know – names and places we don't feel that we have any concern about it – then it is done while we didn't understand the use.

Debesh is facing difficulty in understanding the English words embedded in the mathematics word problems. These students are learning in English which they use at school only. His perception about the relevance of mathematics is mediated by the language as it limits the opportunity to appreciate the utility of mathematics, through word problems. The school curriculum also mediates their perceptions as it directs the students attention to perceiving that mathematics is 'playing with numbers and by not availing word problems from earlier grades (see Meada's story). On the other hand, Abebe appears to be motivated to be engaged in learning of mathematics that involves word problems.

The making of connections between mathematics and other school subjects through word problems has an advantage in exposing to the students that learning mathematics has utility beyond the mathematics classroom or success in examinations. This is particularly important to learners of mathematics in the Ethiopian context where the students have limited access to modern technology which might expose the utility of mathematics (see also Gebremichael, et al., 2011). This has implication for the teaching of mathematics, which will be explained in the conclusion section.

How widely are the perceptions of relevance held?

It has been set out earlier that the results from the pilot study were used to design a questionnaire. Among the 29 items of the questionnaire 4 items are about OSS. The items in the questionnaire pertaining to OSS are: I see mathematics in OSS; I use mathematics in OSS; I see preparatory mathematics in OSS, and I use preparatory mathematics in OSS. These items are likert-type and students were provided the alternatives, 1: strongly disagree; 2: disagree; 3: neutral; 4: agree; 5: strongly agree. Using bar graphs the proportions positive responses in percentage were obtained. The positive responses for the items are calculated as the sum of the proportions for agree and the proportions for strongly agree. The results are shown in the following table (see table 1).

Table 1. The proportions of students' positive responses to the items that establish the dimension 'mathematics as a tool in other school subject'

Items	Proportions positive responses in percentage
I see mathematics in other subjects	92
I use mathematics in other subjects	91
I see *preparatory* mathematics in other subjects	75
I use *preparatory* mathematics in other subjects	79

These items are understood as characterizations of students' perceptions about the utility of mathematics in OSS. There is difference in the proportions of students' positive responses for the items about "mathematics" and the items about "preparatory mathematics". That is, perceptions about mathematics are more widely held than perceptions about preparatory mathematics. This might be because of the range of concepts in "mathematics" as compared to "preparatory mathematics". This difference might also be because of the relatively limited use of *preparatory* mathematics concepts as compared to the use of mathematics prior to preparatory. During the interview sessions as well students told that mathematics in general is useful in other school subjects, while they tell that preparatory mathematics has relatively limited use.

The proportions of students' positive responses to the four items show that these characterizations are very widely held. These characterizations are much more widely held than the characterizations about students' out-of-school life. For example, the most widely held characterization of students' perception about the utility of preparatory mathematics in out-of-school life is the item, 'I see *preparatory* mathematics in my community activities'. The proportion of students who responded positively to this item is 26 %. It has been set out earlier in the results section that students perceive that the other school subjects that utilize mathematics have societal utility than mathematics has. These results have implications for the teaching of mathematics. This will be explained in the conclusion section.

Is there difference in the distribution of students' perceptions across categories?

The four characterizations of students' perceptions reported in this paper are found to be distributed uniformly across the categories of students. That is, there is no statistically significant difference in perceptions across the categories of students (namely, gender, grade level, level of achievement and stream). This was explored using bar graphs. The following graph shows the distribution of students perception characterized by 'I use preparatory mathematics in other school subjects' across grade levels (figure 1).

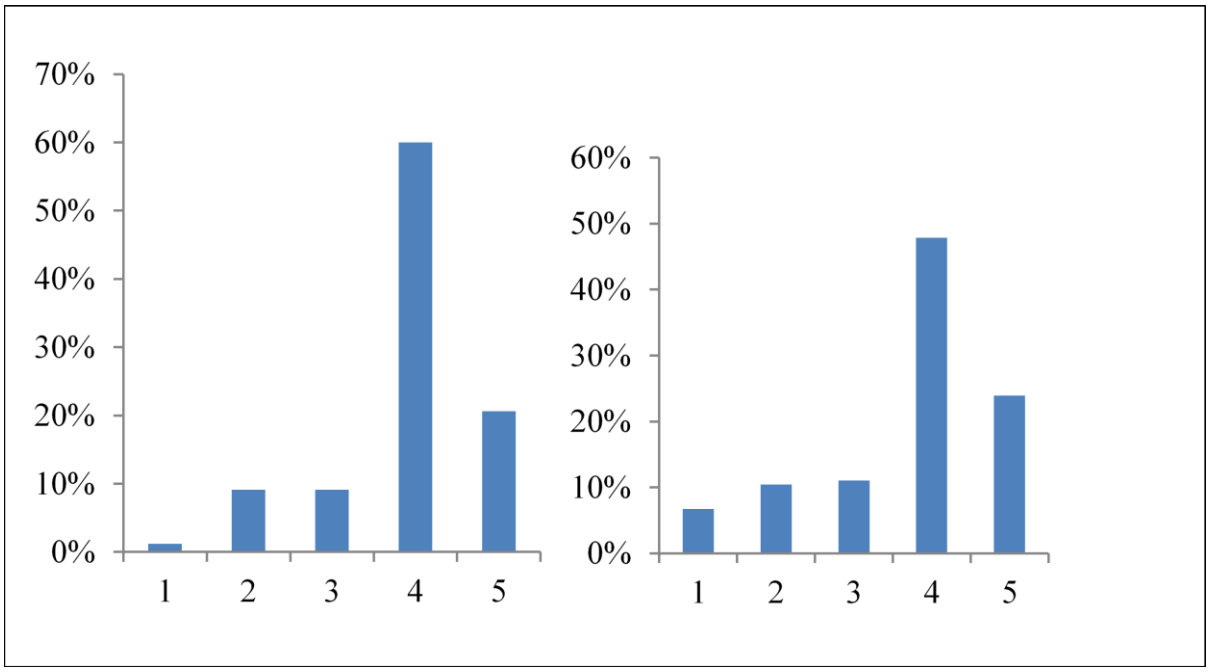

Figure 1. Bar graphs showing the distributions of students' perceptions characterized by the item, "I use preparatory mathematics in other school subjects" across categories of grade level (11th and 12th grade students, respectively).

It can be seen in the bar graphs that the distributions of students' perceptions about the relevance of mathematics to the other school subjects, across categories of grade, are more or less uniform. Similarly, the bar graphs for the other characterizations of students' perceptions of relevance do not show significant difference across grade levels. The bar graphs for the characterizations of students' perceptions of relevance across the other categories are similar. They do not show significant differences.

The availability of differences in the distributions across categories were also tested using the Mann - Whitney U Test. It was found that the test statistic U measuring differences was not extreme ($p>0,005$). Hence the null hypothesis, no difference exists, is retained. The critical value of accepting significance was the more stringent value 0.005. That is, Bonferroni correction has been made because of multiple tests that the data set undergoes. The use of Kruskal- Wallis test (in the case of the three

categories of stream) also showed that there are no significant differences in the distributions of perceptions

The possible explanation for the absence of statistically significant differences in the distributions of perceptions across categories is the similar sociocultural milieu that the students in the diverse categories are situated (see introduction section).

Conclusion

Students perceive that mathematics is relevant to OSS, which appeared to have occurred because of their experiences in mathematics as well as in OSS classrooms. This perception is educationally significant for the following interrelated reasons. First, they are very widely held among the students. Second, for the students, mathematics is one of the school subjects and learning mathematics is one of their multiple goals in their participation in the activity of schooling. Third, students perceive that OSS are relevant to real-life whereas mathematics is rarely related to real-life. The students also told that other school subjects, which utilize mathematics are applicable in the society. Though this last perception is not measured quantitatively, it is possible to conjuncture that this perception is educationally significant. It appears to add to the significance of the perceptions about other school subjects. That is, these perceptions need our attentions in our teaching of mathematics.

The mathematics classroom does not seem to give them much exposure to the students about the applications of mathematics to their own real life situation. The real-life situation of the Ethiopian students does not seem to expose students to real-life application of mathematics. OSS appears to partly compensate for the limited access to artifacts that might expose the application of mathematics (see also Gebremichael, et al., 2011). The OSS appears to be opportunity to boost the students' perception through exposing to the students that learning mathematics has application beyond the mathematics classroom or success in examinations. OSS can be used to popularize mathematics among students in this respect and inspire them.

There are some issues that need attention in this regard. It is set out in the results section that the students were exposed to the application of calculus in physics before they learn it in mathematics. The sequence of topics in the curricula of mathematics and OSS that utilize mathematics is important for boosting students' perception of relevance. Moreover, the curricula of OSS should explicitly inform the required mathematical concepts and the mathematics curricula should inform the applications of the concepts in OSS.

It has been set out that one way of making of connections between mathematics and OSS in mathematics classroom is through word problems. The language of instruction is a challenge in understanding word problems. The teachers are also skeptical about the students' capability of comprehending texts in English language. The instruction language with respect to the students' capability of coping with it needs attention. How to make connection mathematics and other school subjects in the mathematics and other school subjects needs further investigation. An effective use of word problems to make connections between mathematics and other school subjects also needs further investigation. This is particularly important with respect to the learning of word problems using a foreign language.

The students' role in the mathematics classroom also needs attention. Students seem to reflect well in group discussion. The domain specific discussions and reflections seem to be opportunities to enhance students' perceptions of relevance. The mathematics teacher may not have the expertise in the other school subjects. In particularly, s/he may not know what mathematics the other school subjects involve. On the other hand the students appear to be in good position to know the utility of mathematics in the other school subjects they have been learning. Thus, the students' reflection on their learning of mathematics and their learning of the other school subjects is significant. It is significant in exploiting the relationship of mathematics to other school subjects in learning and towards getting the students inspired to engage in mathematics.

The results in this study have implications for teacher education program of mathematics and other school subjects. The results appear to suggest that the teacher education programs need to give more emphasis to the connection between academic disciplines and mathematics. The programs might need to be geared in such a way that the student teachers will have a strong view of exploiting the opportunities that the other school subjects can offer in the teaching of mathematics. Similarly, the other school subjects' teachers also need to be enabled to have the potential of creating an opportunity for their future students to appreciate the role that mathematics plays in their field. This is likely to create a favorable academic milieu in the school setting. An academic milieu that enables the students to exploit the relationships between school subjects in their participation in the activity of schooling in which their actions are directed to the interrelated goals of learning school subjects.

In this research report I have attempted to explore and expose the students' perceptions about the relevance of mathematics to the other school subjects. The application of mathematics beyond the mathematics classroom seems to be a motivational factor to students engaging in mathematics. The access to such utility appears to be limited to the Ethiopian students. The OSS form part of the context in which mathematics is situated. This study gives hint about the significance of utilization of the other school subjects as context for the learning of mathematics for further investigation. Utilizing word problems in making connection between mathematics and the other school subjects needs a significant attention. The effective utilizations of word problems in connecting mathematics and other school subjects requires further investigation using instruments in addition to interviews.

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