Raising Students' Cognitive Skills, Extending Level of Textbook Questions: Can we do Both?

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A key objective of education is to help students develop higher level cognitive skills, such as, analyzing complex situations, making decisions and designing plans, along with learning subject content. While an assumption is that these can be acquired through textbooks, the exercises and questions in textbooks often fail to address higher order cognitive skills. Teachers can help by doing additional activities, but are hard pressed for time or hampered by lack of resources. Our idea to address this problem is to systematically extend textbook questions to address higher cognitive levels of revised Bloom's Taxonomy. We developed additional questions for a computer textbook, for elementary students and conducted a study to examine if students are able to successfully solve these questions.

Keywords: Revised Bloom's taxonomy, Cognitive skills, Textbook

Introduction

The main goal of elementary education is to develop basic abilities in reading, writing, arithmetic and life skills which will help children to grow and lead a better life (Singh, Kumar, & Singh, 2006). Another goal of education is for students to learn the process of solving real-world problems (Hurd, 1998). A broader objective of this training is to help students develop higher cognitive skills so that they can think logically, analyze and take decisions in their later lives.

An assumption in our educational system is that a large part of content knowledge and cognitive skills will be acquired by students through textbooks. A study conducted by the Educational Products Information Exchange institute, found that 90% of classroom teaching and activities are based on what is presented in the textbooks. (Cronnell & Humes, 1980; EPIEI, 1976). Studies on college textbooks show that while content knowledge is sometimes addressed in sufficient depth, the accompanying exercises and end-of-chapter questions fail to address higher order cognitive skills (Trachtenberg, 1973). The situation in school level textbooks is not much different. A study on computer textbooks in school level education found a similar pattern as above. Most textbooks focus primarily on computer usage skills such as entering and editing texts, creating spreadsheets, using a mouse/keyboard, etc. rather than on concepts (Iyer, Baru, Chitta, Khan, & Viswanathan, 2010). The accompanying questions which students are required to answer focus mostly on recalling facts.

Some teachers are motivated to raise students' cognitive skills through classroom activities, using resources other than textbooks. But this is difficult, as it is time consuming and often the prime concern of teachers is to cover the topics prescribed in the syllabus (Shymansky, Yore, & Good, 1990). To promote activity-based teaching, extensive training of teachers is required. A different option which can help in such a situation is to extend the exercises, problems and questions in existing textbooks, so as to accommodate questions which will prompt students to apply higher order cognitive skills (defined according to well-established learning taxonomies). This is much easier that rewriting the textbook or the curriculum itself.

In this study, we focussed on extending the worksheet questions of an existing textbook and tried to provide an opportunity to elementary school students to develop higher order cognitive skills. We chose a textbook series, Computer Masti (2009) that is used in the Computers curriculum at the elementary level. The textbook adopts a learner-centric pedagogy in which children discuss their experiences, discover new concepts and experiment with new ideas. The textbook content simultaneously focuses on student learning of fundamental concepts, as well as thinking skills such as step-wise thinking and logical decision making. It has been pointed out that one cannot separate content from thinking skills such as critical analysis and evaluation, which are best learnt in the context of a subject (Raths, Jonas, Rothstein, Wassermann, 1967; Spache & Spache, 1986). The strategy followed in the Computer Masti books is consistent with the National Curriculum Framework 2005 (NCERT, 2005), which recommends that the primary aim of including information and communication technology in education is to help students make and support decisions in the process of solving real-life problems.

The Computer Masti textbooks contain activities and worksheets at the end of each lesson. In this study, we

investigated the nature of the questions in these worksheets and attempted to raise students' cognitive abilities by having them work at questions in a higher cognitive level. The objectives of our study are to:

1) review existing worksheets and categorize questions according to cognitive levels,
2) systematically develop questions in higher cognitive levels and
3) examine if students are able to successfully solve these higher order questions.

In the subsequent sections, we will discuss how we reviewed worksheet questions in the Computer Masti textbooks according to revised Bloom's taxonomy. We describe how we chose questions to be extended to higher levels and illustrate the process using one detailed example. We then discuss the study we conducted to explore the students' ability to solve these extended higher order questions. Finally, we describe findings of our study: a large number of students are successful in answering questions in higher cognitive levels.

Review of Existing Worksheets in Computer Masti

The textbook

Computer Masti is a textbook series (2009) for teaching computers for classes 1-8. Currently books 1-4 have been published, and work is ongoing for books 5-8. The series is based on a Creative Commons model, in which many authors trained in various disciplines such as computer science, psychology and education have contributed a variety of creative ideas. The book is released under the creative commons, non commercial, share alike licence and can be freely downloaded from the website, *http://www.cse.iitb.ac.in/~sri/ssrvm/*. In this book, each lesson is followed by worksheets, activities and a teacher's corner. The teacher's corner gives a lesson plan, some dos and don'ts, and other tips to the teacher. This textbook series is in use in 6 schools in the state of Maharashtra and 3 schools in the state of Karnataka.

Books 1-4 from this series were chosen for this experiment. The book is in a story format and revolves around three central characters; Tejas, Jyoti (two elementary school students) and Moz (a mouse-like character who is the facilitator). The lessons follow a constructivist pedagogical approach which encourages Tejas and Jyoti to keep asking questions and to explore on their own. The textbook also encourages collaborative learning through various group activities given at the end of each lesson.

Analysis of questions according to revised Bloom's taxonomy

Educators have long considered the Bloom's Taxonomy of learning to be a valid benchmark that measures a student's level of understanding in a particular subject. Bloom's taxonomy is a multi-tiered model which classifies thinking skills under six cognitive levels, namely: knowledge, comprehension, application, analysis, synthesis, and evaluation (Bloom, 1957). It is hierarchical in nature; each lower level thinking skill is subsumed by the higher levels. One criticism about Bloom's taxonomy was that both the 'knowing what' and 'knowing how' aspects of the knowledge category were treated as a single entity. To address the limitations, as well as to fit in the learning-outcome based modern education, a revised Bloom's taxonomy (RBT) has been suggested by Krathwohl and Anderson (2001). In RBT the knowledge category was separated into two aspects; the noun and verb. The 'knowing what' was classified into four levels, namely Factual, Conceptual, Procedural, and Meta-Cognitive. The 'knowing how' or cognitive processes were categorised as remembering, understanding, applying, analysing, evaluating and creating (Krathwohl & Anderson, 2001). In this paper we have focused solely on the cognitive processes, and hence used the RBT with the different cognitive levels being specified as verbs. RBT is more universal than the original Bloom's taxonomy, it can be applied to all levels of education viz. elementary, secondary, and tertiary (Haddad, 2007).

In this study, we analyzed the worksheet questions in each lesson from Computer Masti books 1-4 using RBT. Each book has 7-10 lessons, and each lesson has around 4-7 questions in the worksheet. In addition, each book has questions under the lesson heading 'Projects'. These questions are exploratory and open-ended group activities, hence we did not review them in this study. We categorized the questions in the worksheets under the six levels of the RBT. The percentage of total worksheet questions (in each book) under each category is shown in Table 1. The numbers in the parentheses denote the total number of questions.

	Remembering	Understanding	Applying	Analyzing	Evaluating	Creating
Book 1 (33)	**54.5% (18)**	**36.3% (12)**	**9% (3)**	**-**	**-**	**-**
Book 2 (32)	43.7% (14)	50% (16)	6.2% (2)	-	-	-
Book 3 (25)	24% (6)	44% (11)	24% (6)	8% (2)	-	-
Book 4 (31)	3.2% (1)	32.2% (10)	22.5% (7)	32.2% (10)	6.4% (2)	3.2% (1)

Table 1: Categorization of Computer Masti worksheet questions according to RBT

As we can see from the table, the questions followed a pattern. In books 1 and 2, questions largely belonged to the lower categories under RBT, namely 'Remembering' and 'Understanding'. In books 3 and 4, there was a shift towards the higher categories and some questions fell under the higher thinking order skills.

Developing Higher-order Questions

After the analysis and categorization of the worksheet questions, we selected some questions to be extended. We chose questions for extension based on a few criteria. The questions had to be context-rich and had to relate to everyday situations. We found that questions in lessons that emphasized fundamental concepts such as step-wise thinking were easier to extend than those that dealt with procedural aspects such as editing typed text, start up and shut down. We wrote additional questions belonging to higher and lower thinking orders under revised Bloom's taxonomy keeping the same content and context. In all we extended seven worksheet questions from Books 2, 3, and 4, using the above method.

As an example, we describe how we modified and designed new questions based on a worksheet question in the lesson "Activities Using a Mouse" in Book-2. The objective of this lesson is to help students to practice the concept of organization through mouse skills. The text of the original question is reproduced in Fig 1 to the right.

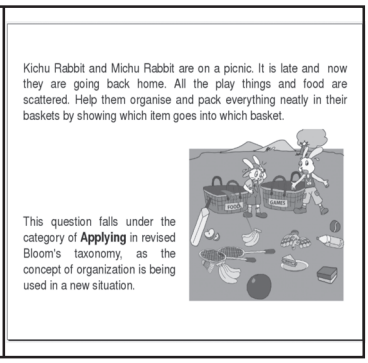


Figure 1: A question from the Computer Masti - Book 2, which was then modified to all the cognitive levels under RBT

We devised different versions of this question to include all the other higher and lower order cognitive levels, but keeping the same context. The different questions are shown in Figure 2.

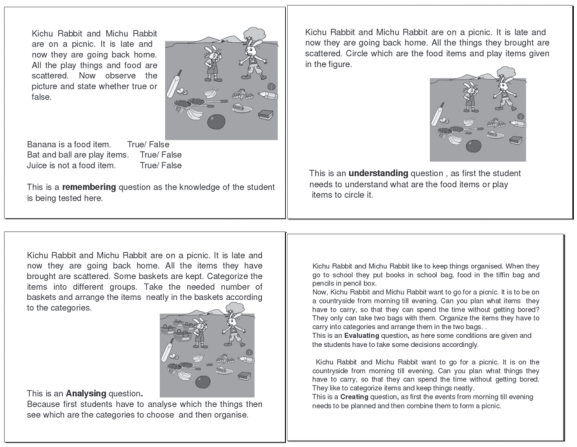


Figure 2: Different levels of the question in Fig. 1, according to revised Bloom's taxonomy

To validate the extended questions, we asked four experts in different domains, namely pedagogy, educational psychology and computer science, to evaluate them. The wordings of the questions were refined according to their suggestions. Each question went through two rounds of refinement before they were given to the students. We followed a similar process for all questions that were extended.

Study Of Students' Ability to Solve Higher Level Questions

Methodology

As students already had exposure to the questions in the lower levels, our study focussed on their ability to solve questions in the higher levels. For this we conducted a study in two schools in Mumbai. Our sample consisted of students of classes 3 and 4. School A had 160 students each in classes 3 and 4 and school B had 40 students in each of the classes 3 and 4, thus giving us a large sample size. Students in both these schools had been exposed to the Computer Masti curriculum. The teachers who taught Computer Masti had undergone a formal training on how to teach the book. The book was taught for one period (30-45 minutes) a week. School A was a public school which followed the CBSE syllabus. Computer Masti had been introduced in this school for a year. School B was a private school which followed the ICSE syllabus. Students and teachers in school B had been exposed to Computer Masti for 3 years.

The questionnaire for our study consisted of a set of three questions in the higher order thinking levels of Analyze, Evaluate and Create in different topics. To try to minimize the effect of the topic, we created three different sets of question. Every set contained one question in each of Analyze, Evaluate and Create categories. Students were randomly given one of the three sets of questions. 65 students answered any given set of questions. Table 2 shows the distribution of topics and cognitive levels in the three sets of questions.

	Analyze	Evaluate	Create
Set 1	Organizing items for a picnic (organizing skills)	Arranging names in alphabetical order (sorting)	Getting ready in the morning (step-wise reasoning)
Set 2	Getting ready in the morning	Organizing items for a picnic	Arranging names in alphabetical order
Set 3	Arranging names in alphabetical order	Getting ready in the morning	Organizing items for a picnic

Table 2: Distribution of topics and cognitive levels in the three sets of questions for Class 3 The parentheses show the fundamental concept underlying the question in the topic

The same procedure was followed to prepare the questionnaire for Class 4. In Class 3 and Class 4 one topic, namely, 'Step wise

reasoning' was kept the same. The questionnaire was given to students as practice questions and no marks were assigned in the question sheet. Students were given 30 minutes to solve the questions.

Data analysis

We scored students' responses on the questionnaire on a four point scale ranging from 0 to 3. The scores can be interpreted as follows: 0-Not attempted, 1-Major errors or incomplete answers, no logical reasoning presented, 2 - Almost correct but needs some improvement and 3 - Fully clear and correct.

The inter-rater reliability was tested between the two authors, and an agreement of 90% was reached. All the questionnaires were scored, we plotted histograms of students' scores to provide descriptive statistics of the sample. We then performed a c^2-test to examine differences between responses of students in different classes.

Results and Discussion

Performance of students across class

Fig. 3 shows the percentage of students in class 3 (N=188) and class 4 (N=185) who achieved scores of 0, 1, 2 and 3 on questions in different cognitive levels. From the histogram for class 3, we can see that 65% of students achieved a score of 2 or 3 in the Analyze level questions, and 40% of students achieved a score of 2 or 3 in the Evaluate and Create level questions. This implies that a significant fraction of students were able to solve questions in higher levels 'almost correctly' or better. Students in class 3 did not have exposure to questions (through the worksheets) in the level above Applying.

The data from class 4 (Fig. 3, second graph) show that 57% of students achieved a score of 2 or 3 in the Analyze level questions, while this number was at 40% in the Evaluate and Create level questions. If we narrow our focus to students who achieved a perfect score, we see that about 50% students received a score of 3 for their responses to the Analyze level questions. From our analysis of categorization of Computer Masti worksheet questions (Table 1) we can see that students in class 4 have had some exposure to Analyze level questions through their regular worksheets, but very little to questions

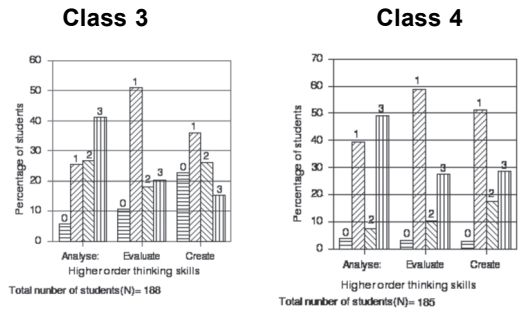
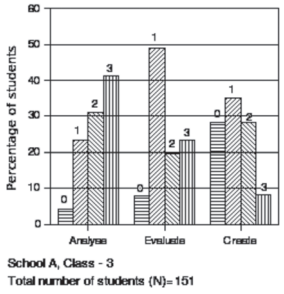


Figure 3: Scores on questionnaire versus total students (in percentage)

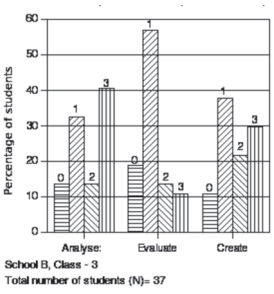
To further explore the differences between students of classes 3 and 4, we performed a c^2-test. The difference in performance is significant for Analyze ($c^2 = 15.69$, df = 9, $p < 0.1$) and Create ($c^2 = 24.62$, df = 9, $p < 0.05$) level questions. We found a non-significant difference ($c^2 = 14.09$, df = 9) in the Evaluate level questions. One way to explain this result is that students in class 4 have had longer exposure to the Computer Masti book and worksheets. The difference in performance could also be due to the natural cognitive development of thinking skills of children in the 8-10 year age group. More study is needed to explore this variation in the performance between Class 3 and Class 4 students.

Performance of students across schools

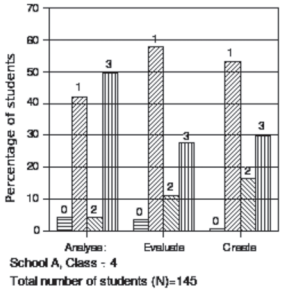
Fig. 4 shows the histograms of student performance on the questionnaire, where the data have been separated by individual schools. The overall trend remains similar in the two schools. A c^2 test revealed no significant differences in the performance of students in the two schools. However, our study has limitations in that the number of students in School B was about 40, as compared to those in School A which was around 160. Secondly, we did not control for factors such as students' prior knowledge and motivation, teachers' backgrounds, socio-economic background of students' families and so on. Hence we need further controlled studies to determine the effect of the school's environment on students' abilities.



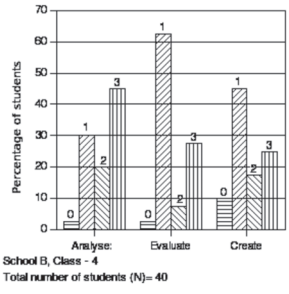
Scores in the 3 higher order thinking skills of students of school A (class 3)



Scores in the 3 higher order thinking skills of students of school B (class 3)



Scores in the 3 higher order thinking skills of students of school A (class 4)



Scores in the 3 higher order thinking skills of students of school B (class 4)

Figure 4: Students' performance on questionnaire, by school (A & B) and class (3 &4)

Summary

In this paper we first surveyed the end-of-chapter questions in a learner-centric computer textbook for elementary school students and found that the majority of questions belonged to lower cognitive levels of revised Bloom's taxonomy. We found that the frequency of questions in the higher levels gradually increased from Book 1 to Book 4, reflecting children's cognitive development as they grow older.

We then systematically applied revised Bloom's taxonomy to develop new questions in each of the higher levels. Through this process we have created a repository of questions in all cognitive levels for several topics. We have had discussions with the authors of the textbooks about the incorporation of the new questions in the next edition of the textbooks.

The results from our study clearly answer the question - can students successfully solve higher thinking order questions? We find that students who have not been directly exposed to higher order questions are able to successfully answer them. Critics have pointed out that complex learning tasks such as authentic real world problems require the integrated use of several cognitive processes (Krathwohl & Anderson, 2001). Thus one might consider that the hierarchy assigned to various questions may be artificial. Yet we find that students, who have only been exposed to remembering and understanding levels of questions, are able to make successful attempts at answering questions that involve skills of analyzing, evaluating and creating. This alone should encourage teachers and curriculum designers to include questions that target higher cognitive levels in revised Bloom's taxonomy.

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