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An Open Learner Model to Help Parents Help their Children

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ABSTRACT

This paper introduces Fraction Helper, a learning environment with an open learner model aimed at helping children to understand their problems with fractions, and helping their parents to help them overcome any misconceptions they hold. Results suggest that the approach of open learner modelling to support parents in helping their children is worth further attention, since both the parents and children found it beneficial. It was also revealed that some parents unknowingly had misconceptions relating to this kind of problem, and so Fraction Helper could be usefully extended to help parents overcome their own misconceptions before they attempt to teach their child their incorrect knowledge.

KEYWORDS

Open learner model, children's and parents' misconceptions, parents' involvement in children's learning, adaptive learning environment.

1. INTRODUCTION

Intelligent tutoring systems usually contain three models: the domain model, which is a model of the expert's knowledge of the domain; the learner model, which is a model of the learner's current understanding of the domain, typically inferred from the student's answers to questions; and the pedagogical model which comprises teaching knowledge or guidance strategies, selected as appropriate for an individual learner at the current time, as inferred from the contents of their learner model.

Traditionally the learner model has not been open to the learner. This has been in part because it can be difficult for the user to understand what their learner model represents, and in part because the primary aim of learner modelling has always been to enable a system to adapt

the interaction to the individual's needs, which does not require the learner model to be accessible to the learner. However, some researchers argue that when the learner model is opened to the user with an appropriate representation, it can enhance learning by promoting reflection and helping a user to plan their learning (see Bull & Kay, in press, for an overview).

Most open learner models (OLM) have been deployed amongst adult learners (e.g. Bull, Quigley & Mabbott, 2006; Kay, 1997; Weber & Brusilovsky, 2001). However, it has been argued that an OLM can be of benefit to children aged 10-11 years (Chen, Deng, Chou & Chan, 2005), 10-13 years (Zapata-Rivera & Greer, 2004), 8-9 years (Bull & McKay, 2004), and even children as young as 7-8 (Bull, Mangat, Mabbot, Abu Issa & Marsh 2005). With open learner models for children, research has been conducted into systems which are designed to be used by both children and their teachers, presenting the child's understanding to both (Bull & McKay, 2004; Zapata-Rivera & Greer, 2004). Giving teachers access to the child's learner model means that they can better appreciate a child's understanding, and are in a better position to help them. Kay (1997) suggests the importance of the learner understanding the teaching goals of a system, and involving a teacher during a child's use of a system could be argued to improve their understanding of the teaching goals. Teacher-child access to the student's OLM could be extended to include parents, so that parents can be given access to a representation of their child's understanding, which may guide them as to how they may best help their child's learning. Using an open learner modelling framework, Zapata-Rivera, Underwood & Bauer (2005) propose the generation of reports which could help parents answer questions such as "what skills or knowledge does my child's performance reflect?" Extending this kind of approach to open learner modelling may enable the benefits available for teacher and child working together to be reproduced at home. There has been much research into the benefits of parents' involvement in their children's education: the UK government suggests that parental involvement would help to improve children's academic achievement (Department for Education and Skills, 2003; Desforges & Abouchaar, 2003); the US Government Department of Education encourages greater family involvement in children's education because children will "complete more homework", "earn higher grades and receive higher scores on tests" and "demonstrate more positive attitudes and behaviours" (Funkhouser & Gonzales, 1997).

This paper describes the investigation of an OLM for child and parent users. In addition to an open learner model for the child, available to both the child and the parent, an extra open learner model was developed for parents based on (and restricted to) the parent's answers to the questions that indicated their child had a misconception. This allows parents to better understand their child's difficulties as they will have experienced what their child had to do. It also indicates whether the parents themselves have misconceptions in the subject area, in order that these can be dealt with before the parent attempts to help their child.

2. FRACTION HELPER

Fraction Helper has the aim of helping to improve children's fraction knowledge by involving parents in their children's learning. The subject matter is Year 5 (age 9-10) fractions from the UK National Numeracy Strategy (2004) content of the National Curriculum for UK schools.

Fraction Helper is not a full intelligent tutoring system - it was developed in the first instance to investigate the potential of an open learner model for children and their parents, and so the focus is on open learner modelling. Nevertheless, Fraction Helper does contain additional features to help support the user's understanding of their progress, such as pictorial question feedback on the correctness of an answer, and supplementary teaching material that explains fundamental fractions that can be accessed by children and parents as they feel the need. Figure 1 illustrates the format of questions, (multiple choice and short answer), text explanations, and the simple pictorial feedback offered.

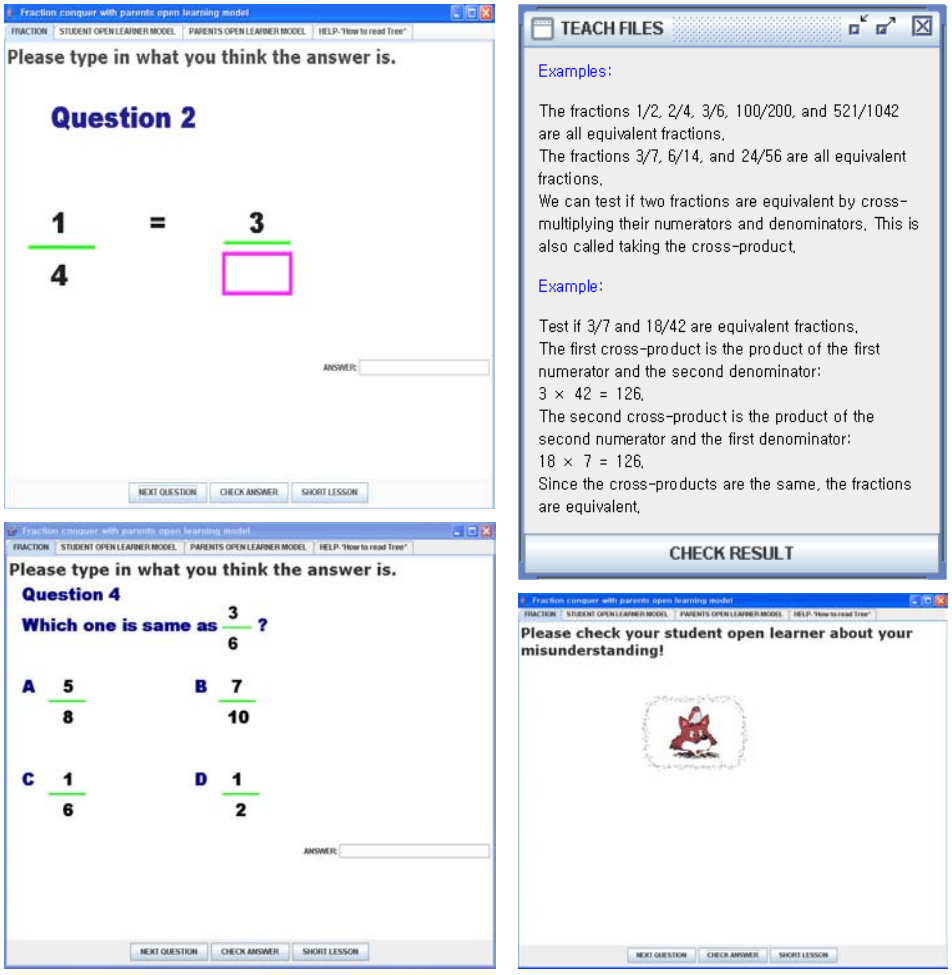

Fig. 1. Fraction Helper questions, explanations and feedback

Examples of the Fraction Helper question types are as follows:

- **Common Denominator**

Simple simplification

e.g. What is the simplified form of $\frac{12}{16}$?

Finding the equal value fraction (understanding the value of fractions)

e.g. Which fraction is the same as $\frac{15}{25}$?

i. $\frac{15}{5}$ ii. $\frac{5}{25}$ iii. $\frac{3}{5}$ iv. $\frac{5}{6}$

- **Fractions and Mixed Numbers**

Conversion of fractions to mixed numbers

e.g. Please convert the improper fraction $\frac{18}{3}$ to a mixed number.

Conversion of mixed numbers to fractions

e.g. Please convert the mixed number $2\frac{3}{5}$ to an improper fraction.

In addition to overall level of knowledge of the above topics, Fraction Helper models the following misconceptions identified from errors occurring during four years of teaching children about fractions (see also Count On, 2006; Newstead & Murray, 1998; and Tirosh, 2000, for misconceptions in this domain).

- Misconception A: **Common denominator means addition** $\frac{1}{4}=\frac{2}{5}$

  A Random number is chosen and that number is added to both the numerator and denominator.

- Misconception B: **Common denominator means subtraction** $\frac{4}{6}=\frac{2}{4}$

A Random number is chosen and that number is subtracted from both the numerator and denominator.

- Misconception C: **Fractions are equal if the numerator is the same** $\frac{4}{6}=\frac{4}{12}$

  The child believes that equivalent numerators indicate equivalent fractions.

- Misconception D: **Fractions are equal if the denominator is the same** $\frac{4}{6}=\frac{2}{6}$

  The child believes that equivalent denominators indicate equivalent fractions.

- Misconception E: **Simplification means cancelling zeros** $\frac{20}{1000}=\frac{2}{1}$

  The child believes that all zeros can be removed

- Misconception F: **A whole number can only be a number featuring in the fraction** $\frac{4}{6}=4,\ \frac{4}{6}=6$

  The child believes that a whole number can only be either the numerator, denominator or the single number in the fraction.

- Misconception G: **A sequential number is used to multiply** $\frac{2}{4}=\frac{2\times 3}{4\times 4}=\frac{6}{16}$

  A sequential number is chosen to multiply (e.g. 3,4)

- Misconception H: **A sequential number is used to simplify** $\frac{8}{10}=\frac{8\div 1}{10\div 2}=\frac{8}{5}$

  A sequential number is chosen to divide (e.g. 1,2)

Fraction Helper models knowledge level over the last 10 attempts at answering questions on a topic, on 5 levels of knowledge: the highest level reflecting full understanding; the second highest level, good understanding; the third level, fluctuating/developing knowledge; the final levels, weak, and very little/no knowledge. Misconceptions are identified over the previous three attempts by comparing input to a misconceptions library. If the misconception was demonstrated in 2 of these last 3 responses, it is recorded in the learner model. This allows misconceptions to be represented independently of knowledge level - i.e. the same misconception may be present at several stages of the learning process.

The example below illustrates the benefits that learner modelling and attention to question design can bring over a simpler system that may produce more traditional feedback focussing on the correctness or otherwise of answers. In the example, Student A answered the

first 5 questions correctly, but the last 2 incorrectly. In contrast, Student B answered the first 4 questions incorrectly, but the last 3 questions correctly.

Student A: $\frac{9}{3}=3,\ \frac{16}{4}=4,\ \frac{25}{5}=5,\ \frac{36}{6}=6,\ \frac{4}{2}=2,\ \frac{27}{3}=3,\ \frac{20}{4}=4$

Student B: $\frac{36}{3}=3,\ \frac{12}{2}=2,\ \frac{6}{2}=2,\ \frac{16}{2}=2,\ \frac{27}{3}=9,\ \frac{30}{6}=5,\ \frac{20}{4}=5$

Despite student A providing the correct answer for 5 questions and student B giving the correct answer for 3 questions, both students held the same misconception (a whole number has to be a denominator from the fraction). Here the nature of the first 5 questions given to Student A allowed them to give the correct answer despite holding the misconception. Student A's feedback might be 5 correct answers with 2 incorrect answers, whilst Student B's feedback is 3 correct answers with 4 incorrect answers. Based on the feedback, Student A would score a higher mark than Student B, which would make it seem that Student A's knowledge of fractions is greater. However, unlike Student A, Student B resolved their misconception once they reached their last questions. Considering only their latest knowledge, Student A can be seen to hold a misconception whilst Student B would be seen not to carry that misconception. It can be seen that if more general feedback was provided in the form of a performance score, it would not necessarily reflect the student's current knowledge level because the feedback simply provides information on correct or incorrect answers and includes information that may no longer be relevant if the student has learned during the interaction. A learner model allows provision of more accurate detail about a student's learning, because it models their *current* understanding.

We would not want to have a modelling depth of only 1 question, as this could lead to problems in the learner model. For example, Student B may have got their last question correct by guessing, and in fact, still hold the misconception. Likewise, Student A may have had a lapse of concentration and made a simple mistake; actually understanding the concept fully. With a 1 question modelling depth, the student's recent history is left unused, and anomalous answers could cause learner knowledge to be modelled incorrectly. Fraction Helper employs a depth of 3 questions to identify misconceptions, as in this example. 3 questions are considered sufficient for modelling misconceptions in this system since the questions in the topics address specific concepts (rather than a broader collection of concepts). Using only the more recent responses in modelling means that the learner model avoids holding information that is no longer representative of the learner's misconceptions. It is therefore information about current

understanding that is presented to the learner in their OLM, which is accessible to the child at any time.

3. THE FRACTION HELPER OPEN LEARNER MODEL FOR CHILDREN AND PARENTS

This section describes the externalisations that present the child's and parent's open learner models.

3.1 Open Learner Model for Children

The OLM for children (Figure 2) provides information on the child's knowledge state: a growth based pictorial representation (tree icon) to indicate knowledge level and the existence of misconceptions (sad trees), and text stating any misconceptions held. These are labelled 'misunderstanding' in Figure 1, to aid comprehension of the feature by children. Fraction Helper uses the same terminology used in the classroom, to support students' understanding of the descriptions. In order to understand their tree icon the children can refer to the tree icon key at the top of the screen, labelled "Help. How to read Tree".

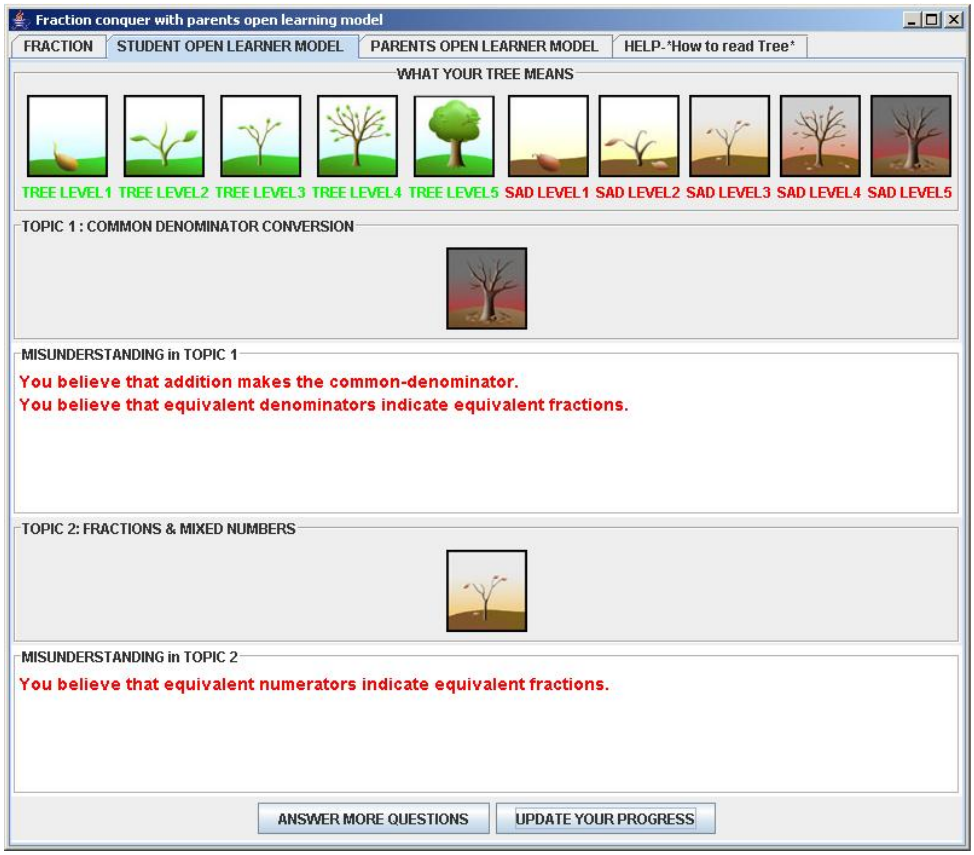

Fig. 2. The open learner model for children

There are 10 tree icons. The first 5 indicate knowledge level where there are no misconceptions, and are green indicating healthy trees. When the tree icon depicts a seedling, or "TREE LEVEL 1", it means that the child has just started using the system and based on the questions that they have answered so far, the system has not detected any problems or misconceptions; or that the child has attempted several or even many questions getting the majority of them wrong, but in such a way that the system does not consider them to hold any specific misconceptions (i.e. they may just lack the knowledge to answer the questions). TREE LEVELs 1, 2, 3, 4 and 5 represent increasing knowledge level, with 5 showing expert knowledge.

When the child receives a tree icon depicting a dying seedling or tree, or "SAD LEVEL" (which has a reddish hue), it means that the child has demonstrated that they hold one or more misconceptions. The level (e.g. SAD LEVEL 3) still relates to the overall knowledge level for the topic, as can be seen by the basic similarity of the equivalent TREE LEVEL and SAD LEVEL images. Because the recording of misconceptions in the learner model is based on the last three consecutively answered questions, the child can have their "sad tree" icon quite quickly changed to a growing tree icon if they resolve their misconception, displaying correct knowledge over three more questions. In addition to the sad trees, red text provides details of the misconceptions.

When the child clicks on the 'student open learner model' tab, the information presented does not initially reflect their current knowledge status; instead it is of their previous knowledge state. To be presented with their current learner model information, the child has to click the 'update your progress' button at the bottom of the screen. This feature has the aim of increasing learner awareness of their learning. By clicking on a button to update their learner model presentation from its previous state when last viewed, to the current state, the student can gain a better sense of their progress through a clearer comparison of their previous and current knowledge levels; for example, they may see their trees grow and their misconceptions disappear. The display of the five TREE LEVELS and SAD LEVELS at the top of the screen also helps the child easily identify their current position with reference to the target (level 5).

3.2 Open Learner Model for Parents

Parents can view their child's OLM. They can also answer the fraction questions in which their child showed misconceptions. The questions are the same as those used for constructing the child's learner model, with the aim of helping parents to appreciate what the child had to do, before they attempt to help them overcome their misconception. This also allows Fraction Helper to identify whether the parents themselves have any difficulties with the material that they will be trying to explain to their child. If the parent also has misconceptions, the parent is

alerted to this through *their own* OLM covering the restricted area in which their child had difficulties (also displayed as in Figure 2).

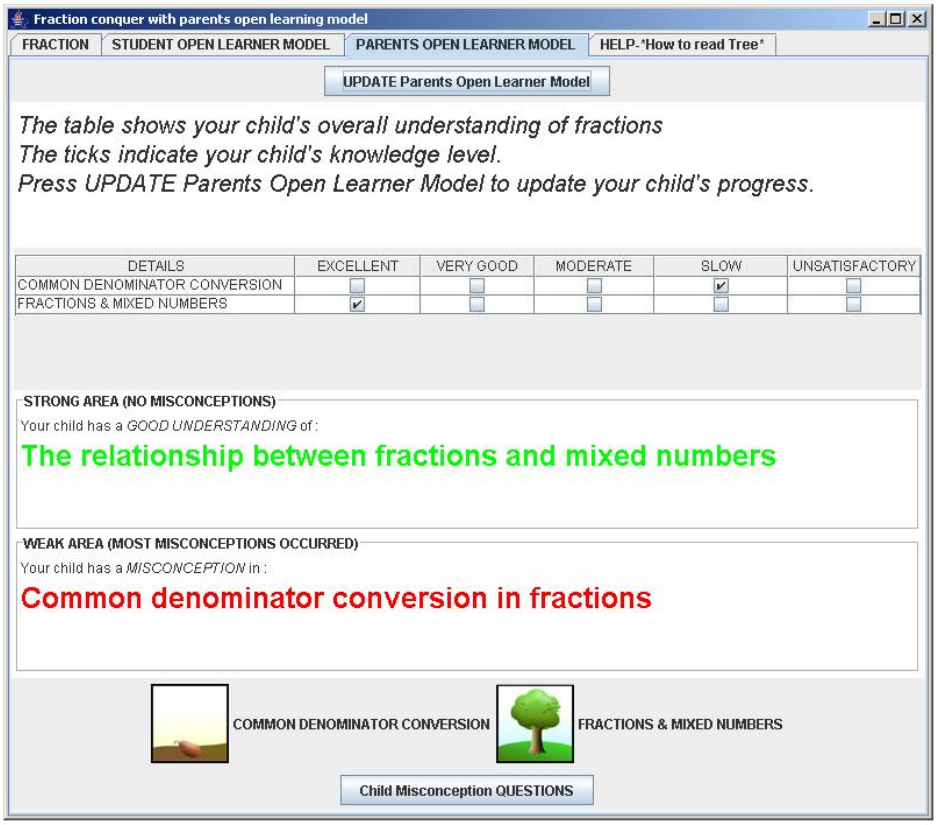

Fig. 3 The parent's view of the child's knowledge

Figure 3 is an example of an additional presentation for the parent, of the child's learner model information. This has three components to present the child's knowledge level and misconceptions, to be viewed by the parent alongside the child's OLM. The ticks in the table corresponds to the child's knowledge level (as this may be more intuitive to parents than the trees). The text provides information of the child's weak and strong areas from the topics that the child attempted. Green text indicates a good understanding and that no misconceptions occurred, whilst red text written beneath the "weak area" heading provides information on misconceptions if the child has displayed any. The image indicates the child's knowledge level. When the current image shows that the child has a misconception by portraying a dying (or sad) tree, the questions for which the child displayed misconceptions will be available for parents to experience. The button, 'update parents open learner model' (i.e. the parent's version of the child's OLM) lets the parent compare the child's previous and current learning states, just as the update button does in the child's OLM. This additional view of the learner model is available

simply to allow the parent to gain a quick overview of their child's strengths and weaknesses, to help guide them in where most help is required.

4. THE POTENTIAL FOR AN OPEN LEARNER MODEL FOR CHILDREN AND PARENTS

An evaluation was undertaken to investigate the effectiveness and potential benefits of open learner models for children and their parents, to identify whether further work in this area is likely to be worthwhile.

4.1 Participants

Participants were 22 Year 5 (9-10 year old) children and 20 parents from two Birmingham schools. The group comprised 15 boys and 7 girls, and included two sets of twins and one set of triplets. All children participated with one of their parents. In the case of the triplets and one of the sets of twins, one parent took part twice (i.e. with two children). There were 8 female parents and 12 male parents. The parents of children from both schools had varied levels of education ranging from middle school level to university level.

4.2 Materials and Methods

The study consisted of a pre-test, system use by the child, system use by the parent if their child had a misconception, child-parent discussion, a post-test, a questionnaire and a semi-structured interview. System logs and video recordings were also used.

The system use took place in the participants' homes as Fraction Helper is designed for use at home, thereby reproducing as far as possible the intended context of use. Children first used the system individually. The parents then looked at the open learner model and attempted the questions for which their child had misconceptions. After both the children and parents finished using the system, the parents conversed with the child about their knowledge. No constraints were placed on any part of the interaction.

The pre-test before system use and post-test after the child-parent discussion that were administered to the children, each consisted of 10 questions. These were made up of a mixture of short answer questions and multiple choice questions of the same format and to the same standard as the question content of Fraction Helper. The pre-test and post-test each had an approximate duration of 10 minutes.

There were two sets of questionnaires completed at the end of the session: one for children and one for their parents. The child's questionnaire asked them to state the usefulness, effectiveness and motivational effect of their OLM. The parents were asked to comment on the

usefulness of having access to their child's OLM, and to their own OLM based on their answers to some of the questions attempted by their child.

Finally, interviews were used to record unique reactions and individual responses to the system. Children and parents were interviewed separately and the interviews were structured to gain additional information of the participants' thoughts about the utility of the open learner model for both the children and parents. Additionally, whenever a participant gave an interesting response, this was followed up by the experimenter.

The system logged the interactions of all participants (children and parents), and the interactions were also video-recorded. With permission of participants, 8 of the child and parent interviews were also video recorded (the remainder declined to have the interviews recorded).

4.3 Results

Table 1 shows the results of the pre-test and post-test (out of 10).

Table 1 – Pre-test/post-test results (out of 10)

Student No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Pre-test score	6	6	5	7	10	5	3	1	3	4	0	9	9	6	7	6	5	5	5	7	7	5
Post-test score	10	10	10	10	10	10	10	7	10	8	9	10	9	10	10	10	10	9	10	7	10	9
Improvement	4	4	5	3	0	5	7	6	7	4	9	1	0	4	3	4	5	4	5	0	3	4

19 out of 22 children (86%) made an improvement in their post-test score from their pre-test score, with three children scoring equally on each test. All 5 children scoring lower than 5 in the pre-test improved at least 4 points in the post-test (range 4-9; median 7), with 2 achieving the maximum score of 10 in the post-test. Those scoring 5 or higher in the pre-test mostly scored 10 on the post-test (13). 3 scored 9 (1 of whom also scored 9 on the pre test); and 1 scored 7 (also scoring 7 on the pre test).

Children used Fraction Helper for between 25 and 35 minutes. Table 2 shows each participant's usage as indicated by the system logs.

Table 2 – Usage levels (system logs)

Student	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Questions	19	20	20	26	20	22	20	20	25	18	20	30	20	17	20	20	25	20	22	20	20	20
View OLM	9	17	20	17	3	15	4	7	13	12	20	12	5	16	7	16	15	10	18	4	8	9
Views/Q	2	1	1	1.5	7	1.5	5	3	2	1.5	1	2.5	4	1	3	1	1.5	2	1	5	2.5	2

Table 2 shows that children answered between 17 and 30 questions each (mean 21, median 20). Each participant viewed their OLM, and 13 children (59%) were reading their OLM more than 10 times whilst solving fraction questions through the system, 9 of these (41%) consulting their learner model 15 or more times (maximum 20). The mean number of OLM viewings was 12, and the median 12. 14 children (64%) were viewing their learner model after answering 1 or 2 questions; the remainder less frequently (the least frequent being an average of 7 questions between learner model inspections by the student who was already proficient in fractions as indicated by the maximum pre-test score).

Table 3 shows the questionnaire responses relating to whether the Tree and Text misconception description components of the OLM were considered motivating, understandable and helpful.

Table 3- Perceived utility of OLM (questionnaires)

Questionnaire Responses	**Strongly agree (5)**	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly disagree (1)**	**Mean**	**Median**	**Range**
Tree: understandable	4	14	4	0	0	4	4	3-5
Text: understandable	3	7	12	0	0	3.6	3	3-5
Tree: motivating	6	13	3	0	0	4.1	4	3-5
Text: motivating	0	5	10	6	1	2.8	3	1-4
Tree: helpful	2	13	3	3	1	3.5	4	1-5
Text: helpful	8	10	3	0	1	4	4	1-5

Most of the children agreed that the Tree icons were motivating (19 - 86%) and understandable (18 - 82%). Only 5 children (23%) provided a positive response to the Text component being motivating, but 10 (46%) reported that they understood it. There were 10 (46%) and 12 (55%) neutral responses for the textual misconception descriptions being motivating and understandable, respectively. However, there were a greater number of children stating that the Text misconception description was helpful (18 - 82%); whilst 15 children (68%) agreed that the Tree icon was helpful. In each case there were 3 neutral responses.

The following excerpts from the children's interview transcripts provide more detail (E= experimenter, S= student).

E: Did you know what was meant by 'misunderstanding'?

S2: Yeah. That means I do not understand my maths.

E: When you read the words in the misunderstanding box, did you try to solve the questions in a different way from before?

S1: Yes. Because I got a sad tree. I did not want to get sad trees.

E: What does the sad tree mean?

S1: I didn't know my fractions.

E: Can you tell me the reason why you did not look at the open learner model often?

S12: When I checked my answers, they were correct. I did not have any problem so I checked whenever I felt like checking

E: So why were you looking at your open learner model?

S12: Because it was fun to see how the tree was growing. So whenever I feel like checking my trees, to check if my tree grows well, then I check.

E: Can you tell me the reason you answered a lot of questions?

S4: I just want to get the big oak tree.

S12: I wanted my tree to grow biggest. If I answer more questions and I get them right, then my tree grows more. It's so cool.

S17: If I do more questions and get them right, then I get the big tree, right? The biggest tree means like I am the master of fractions, right?

Supporting the questionnaire responses, the interview transcripts show that the children appear to understand their current knowledge level by looking at the Tree icon. In the examples shown here, S1 and S2 identified a 'sad tree' as representing misconceptions and clearly stated that this implies they have incorrect knowledge.

S12 suggested that the Tree icon motivated her to view her open learner model, and S4, S12 and S17 stated that the Tree icon motivated them to answer more questions in order to grow their tree.

Table 4 indicates which children had misconceptions at some point during the interaction, as indicated in their learner model, and whether their parent also held a misconception for that type of problem (recall that parents only answered questions that elicited misconceptions from their children). Children also stated whether working with the parent was helpful; and parents stated their confidence in their knowledge of Year 5 fractions. A mother participated in this evaluation with both of her twins. The triplet participant children used the

system with both of their parents. The father interacted with two of the triplets, and the mother interacted with the third. (To preserve anonymity we have assigned two separate participant numbers to parents working with two children.)

Table 4. Child and parent misconceptions (learner models)

Student	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Child: had misconceptions	A	B	C	D, G		D	B, D	B	F	E	A, E	D		F	D	E	E, F	A, C	A		B	C, E
Child: parents helpful	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Parent	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Parent: had misconceptions		B		G			B	B			E			F				A	A			
Parent: high confidence	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

Table 4 shows 19 children (86%) having misconceptions, and 8 children being helped by a parent with a misconception in the same area that they held a misconception themselves. Nevertheless, all participating parents thought their knowledge of fractions was good. (The letters relate to the misconceptions listed previously in Section 2.) It can be seen that a range of misconceptions occurred amongst the sample. All children except S5, who had good knowledge from the start, stated that their parent's help was useful.

The results of the questionnaires regarding how helpful the parent participants found the OLM for understanding their own and their child's knowledge level is shown in Table 5. Additionally, the responses to whether solving their child's misconception questions helped them to understand their child's misconceptions, as well as whether doing so was useful for identifying their own misconceptions, are shown. Most parents' answers suggest that the OLM was helpful, with both OLM questions receiving positive responses. 17 of the 20 parents (85%) gave a positive response to whether the OLM was helpful in understanding their child's knowledge level, with no negative responses, and only 3 neutral responses. (The responses indicating that the OLM was helpful included that of the parent whose child stated that their parent was not helpful.) 13 parents (65%) found their OLM useful in understanding their own knowledge level, with 7 neutral and no negative responses.

Table 5. Perceived utility of parent's OLM (questionnaires)

	Strongly agree (5)	**Agree (4)**	**Neutral (3)**	**Disagree (2)**	**Strongly disagree (1)**	**Range**
OLM: helpful to understand child's knowledge	9	8	3	0	0	3-5
OLM: helpful to understand own knowledge	3	10	7	0	0	3-5
Answering questions: helpful in understanding child's misconceptions	8	11	1	0	0	3-5
Answering questions: helpful to identify own misconceptions	7	6	5	2	0	2-5

Responses to solving their child's misconception questions were also generally positive, with 19 parents (95%) finding answering the questions helpful in understanding their child's misconceptions, and only 1 neutral response. 13 parents (65%) responded positively to the question of whether answering the questions was useful in identifying their own misconceptions. 5 parents gave a neutral response, and 2 disagreed.

The following excerpts from transcripts of the interactions between the parents and their children illustrate the kinds of interaction that took place. Fractions in brackets show what was written by the parent on paper during the discussion.

A parent with good knowledge helping their child overcome a misconception

P10: Have a look at this fraction, 10 over 2 ($\frac{10}{2}$). If you have to simplify the fraction into a whole number, what do you think the answer is?

S10: Is it 10?

P10: Do you think the 10 on top of the fraction is the whole number?

S10: [Pause]

P10: How many 2s are there in 10?

S10: [Pause] There are 5 2s in 10.

P10: Yes. That is right. You can always think of how many bottom numbers are in the top number. So what do you think the answer is, then?

S10: 5?

P10. Yes, that's right. It's easy isn't it?

P10 had a good knowledge of fractions. Using their own knowledge, the system's indication of their child's misconception and their experience of the child's misconception questions, they were able to directly address the misconception that their child held.

A parent teaching their child their own misconception

P2: Sweetheart, look at this fraction, 8 over 12 ($\frac{8}{12}$). If you want to get the simplest form of it, what do you have?

S2: It is 2 over 3 isn't it?

P2. No, the first thing you need to do is to subtract the equal number. The smallest number you can divide 8 by is 2, so what you need is 8 minus 2 over 12 minus 2 is 6 over 10 ($\frac{8-2}{12-2} = \frac{6}{10}$). Then you need to keep subtracting until you can't subtract any more, so 6 minus 2 over 10 minus 2 is 4 minus 8 ($\frac{6-2}{10-2} = \frac{4}{8}$) and then 4 minus 2 over 8 minus 2 is 2 over 6 ($\frac{4-2}{8-2} = \frac{2}{6}$).

S2: Oh, so the answer is 0 over 4?

P2: [Pause] Hold on, I made a mistake. Well it must have gone wrong half way, I'll teach you later. Just stick with what you have done for now.

The above excerpt illustrates the kind of difficulties parents can have when trying to help their children. Although S2 actually provided the correct answer, P2 tried to help their child resolve their 'problem', but unknowingly held a misconception themself and so was teaching their misconception to their child. (It should be noted that S2's learner model indicated that they did hold the same misconception - see Table 2 - but at this stage they were on the point of overcoming it.)

A parent noting their own misconception, and helping their child overcome the misconception

S14: What is the whole number of 7 and 8 over 8 ($7\frac{8}{8}$)?

P14: Well, it is 7. 8 over 8 is 1. So 7 times 1 is 7.

S14: Yeah! But when I put that answer, the computer said it was wrong!

P14: Oh! The computer said it was wrong? [Pause] Ah! I remember now, that's a misunderstanding. It is not multiplication. Instead of times you have to add. 7 plus 1 is 8 (7 + 1 = 8). Well, we can make this an improper fraction. So, 8 times 7 is 56 and 56 plus 8 is 64. Now, we have 64 over 8 ($\frac{64}{8}$) and there are 8 8s in 64. So the answer is 8.

The final excerpt shows that P14 held the same misconception as their child. However, through experiencing their child's misconception for which they originally also held the same misconception, the system helped them identify their error by explaining the misconception in the 'misunderstanding text'. When they tried to help their child, the child remembered that the answer the parent gave was stated as incorrect by the system. This helped the parent to remember the misconception that they experienced, allowing them to realise what they had done wrong, and so in turn teach their child the correct method.

The parents' comments during their interview suggested that they were all confident in their primary school level mathematics knowledge before interacting with the system. All parents also stated that they had involvement in their children's learning. Extracts from the recorded interviews are given below. (E = Experimenter, P = Parent)

E: How much time do you spend helping your child?

P1: Well, I help my child when he asks for it. Sometimes, I help more than 3 hours. There isn't any set time for helping my child.

P2: Basically I help with his school homework. I can say two hours every day.

P17: At least 30 minutes per day.

P21: We both try to help our children if they need any help with their school homework.

E: Did you understand the misconceptions your child had?

P15: Yes. I answered the questions and it was a very good method to understand my child's misconception.

P20: It was useful to have a set of questions for me to do. It was easier to understand the kind of misconceptions my child had.

E: Did you realise that you also had misconceptions in the fractions?

P2: No, I didn't know that I had misconceptions. I was really good when I was at school.

P18: It is very embarrassing but I think it is better to have correct understanding about fractions. I help with my child's homework and I am worried that my misconceptions might affect her studies. I guess I need to study again.

P19: I thought I knew fractions quite well.

Whilst Table 4 showed some parents carrying misconceptions about fractions, all parents had a strong positive belief in their knowledge. All had stated that their mathematical skills were adequate to solve primary school standard mathematics. The parents who displayed misconceptions for the fraction questions appreciated the revelation of this information and subsequent new ability to pass correct knowledge on to their children. Some parents (e.g. P15, P20) who did not display misconceptions in the fractions also found that answering the questions was useful to understand their children's misconceptions.

4.4 Discussion

The child participants had varying levels of knowledge of fractions before interacting with Fraction Helper, though all had been taught fractions at school (U.K primary school Year 5 mathematics). Our focus in this paper is on parent and child use of Fraction Helper, rather than on learning gains. Nevertheless, it is useful to demonstrate that our discussion of the system use takes place in the context of a successful approach. Table 1 suggests that Fraction Helper, including the parent-child discussion, helped to improve children's fractions with the majority of students (19 of the 22 - 86%) achieving a better score from their pre-test to post-test. Children of all abilities improved, but those with a lower starting level had more scope for improvement, and did indeed generally increase their pre test to post test scores more. Of course, improvement could simply be due to time on task which could have been achieved through some other approach, but our interest here is on the potential for supporting parents to help their children, based on raising both children's awareness of their difficulties, and parents' awareness of their child's problems and any difficulties they have themselves. This appears to have been achieved.

Table 2 shows that all children consulted their OLM, with 14 (64%) viewing it each time after answering 1 or 2 questions. The least frequent viewing (after answering 7 questions on average) was by the child with the maximum pre-test score (S5); with the remainder answering up to 5 questions between viewings. Thus it seems that the children were finding their OLM a useful form of feedback in addition to the simple information about the correctness of an answer, presented after each attempt.

Table 3 indicates that most of the children were driven to achieve a fully grown tree, with 19 (86%) stating in the questionnaires that their Tree icon was motivating. Additionally, many children stated they wished to have a fully grown tree in their interview when explaining the number of questions attempted. Of course, the Tree icon may be motivating some children to answer more questions rather than them wanting to use the system to *learn*. However, while we would clearly prefer students to want to learn, even if learning is only a 'by-product' this is still a useful outcome at this stage of the research. This is emphasised by the fact that although only 5 children (23%) found the misconceptions text motivating, 18 (82%) found it helpful (compared to 15 (68%) stating that the trees were helpful). Moreover, of the 18 finding the text helpful, 10 'strongly agreed' with the statement, while only 2 'strongly agreed' that the trees were helpful. Nevertheless, only 10 children (46%) claimed to understand the misconception descriptions – this suggests that these may have been helpful for some in conjunction with working with a parent, but not necessarily when working alone. (As indicated in Table 4, all but the student with the highest initial knowledge found working with their parent to be helpful.) For those who did understand the misconception descriptions, given the above finding it may be that some felt a need for the text representation to better support their understanding of their misconceptions so that they could in turn achieve a better growing Tree (rather than aiming to understand their problem). Whatever the reason, it seems useful to include both types of information (trees and misconception descriptions) in the OLM.

Table 4 shows that although all parents had high confidence in their knowledge of Year 5 fractions, 8 children (36%) were working with a parent who had a misconception in the same area as themselves. All parents stated that they spend time helping their children (e.g. homework, extra school work and general questions), and all but one child considered their parent's help useful. But clearly, a parent with a misconception is unlikely to be able to help a child appropriately, if the child also holds a misconception - as can be seen from the transcript excerpts from the parent-child interactions where parents were initially trying to teach incorrect information (as shown for P2 and P14). While P14 subsequently realised their problem after feedback from Fraction Helper, P2 taught an incorrect method to their child even though the child had initially provided the correct answer. Although realising they had made an error, the parent did not realise that the child's answer was correct, and left the child believing that there was a problem. There is therefore an argument for a system such as Fraction Helper being beneficial when children seek help at home, rather than from a teacher who will teach the correct concepts, if it can also help parents overcome their difficulties. Furthermore, the questions that the parents attempted which determined whether they held misconceptions, were only the questions related to their child's misconceptions. This means that the parents could feasibly have held other misconceptions where their child had no problem (or a different

problem), but which would not have been revealed by the system due to its focus on the child's difficulties. Further study could reveal the effects of parents' help when the parent holds misconceptions that their child does not.

An interesting finding was that, although the system identified the misconceptions given in Table 4, P14 was identified as having misconception F, when the excerpt shows that the misconception they held did not conform to the definition of F. This is because the misconceptions are based on common children's misconceptions, not those of adults - which might be a mix of more advanced knowledge incorrectly applied together with partially forgotten fraction knowledge, or partial forgetting combined with some existing knowledge, etc. Here P14 may be confusing the calculation of fractions with their knowledge of algebra, where multiplication of operators is implicit, rather than adding adjacent numbers as required for fractions. Research investigating the extent to which adults hold different misconceptions to those identified for children, and the nature of those misconceptions, would be useful for our approach.

Table 5 shows that 17 parents (85%) found the OLM useful to understand their child's knowledge, and 13 (65%) found it useful in understanding their own knowledge. 19 (95%) found answering the questions themselves helpful to understand the child's misconceptions, and 13 (65%) to understand their own misconceptions. This is interesting given that most of the parents did not have misconceptions – parents nevertheless appeared to appreciate confirmation of their knowledge even though they had felt confident of their ability. The results for use of the OLM for understanding their child's understanding do seem to support the use of such an aid to externalise the learner's knowledge state. The excerpts from the interview transcripts further support this, particularly with reference to misconceptions. It would be useful now, to investigate the potential for more detailed descriptions for parents, and perhaps additional support in teaching. Also, given parents' acceptance of their own OLM, it appears that parents might be open to coaching related to their own difficulties before they attempt to assist their child. The transcript excerpts from the parent-child interactions indicate a role for this, as it can be seen that parents may abandon their attempt at helping the child once aware that they have a problem (P2), if they do not realise their error (as occurred successfully with P14). The very fact that governments encourage parental involvement in their children's learning, and that parents in at least some contexts, are keen to help their children even though they are not necessarily competent in the material themselves, suggests a role for this kind of open learner modelling approach in a child-parent learning interaction.

5. SUMMARY

This paper has described the study of an open learner model for children and their parents. The results suggest that both the children and parents found the open learner model useful; the parents with reference to their own knowledge as well as that of their children.

Parents stated that answering the questions for which their child had misconceptions was useful in helping them to understand their child's difficulties. Parents also revealed that their open learner model allowed them to recognise their own fraction knowledge, and appreciated that they would need to gain the correct knowledge if they wanted to help their children.

These findings suggest that it would be useful to investigate the approach with a larger number of participants over time; investigate possibilities for coaching parents where necessary; and the provision of more detailed learner model information for parents, about their children's knowledge. This has potential as parents appeared to like being part of their children's studies, and were keen to help effectively.

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