Motivating the learner: an empirical evaluation

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Abstract. The M-Ecolab was developed to provide motivational scaffolding via an on-screen character whose demeanour defended on modelling the learner's motivational state at interaction time. Motivational modelling was based on three variables: effort, independence and the confidence. A classroom evaluation was conducted to illustrate the effects of motivational scaffolding. Students had an eighty minute interaction with the M-Ecolab, divided into two sessions. The results suggested a positive effect of the motivational scaffolding, particularly for initially de-motivated students who demonstrated higher learning gains. We found that these students followed the suggestions of the on-screen character which delivered personalized feedback. They behaved in a way that was conducive to learning by being challenge-seekers and displaying an inclination to exert more effort. This paper gives a detailed account of the methodology and findings that resulted from the empirical evaluation.

1. Introduction

Can we increase students' motivation to learn? This question has shaped the nature of research on motivation in education since the 1930's and constitutes an active field of research in Artificial Intelligence in Education [1]. Motivation has been understood as a crucial factor affecting learning behaviour and is a complex phenomenon influenced by a plethora of circumstances that surround the learning experience. Intelligent Tutoring Systems (ITS) have made use of some elements proposed in Theories of Motivation: examples include the works of Lepper [2], Malone [3] and Song [4]. Our approach consists of modelling the learner's motivational state during the interaction and adapting the motivating reactions according to the model's beliefs. We have elaborated on previous work [5, 6] and have added a motivational modeller for an existing ITS, the Ecolab [7, 8]. This paper describes an evaluation of M-Ecolab, the enhanced version of Ecolab. The aims of this paper are two-fold. First, we present findings with respect to the effects of the motivational scaffolding in M-Ecolab using the methodology employed in two previous evaluations of Ecolab [8, 9]. Second, we compare and contrast the outcomes of the three evaluations.

2. Motivational scaffolding in the Ecolab

The Ecolab [7] is an ITS designed for teaching pupils aged 9-11 years-old concepts related to food chains and webs. It consists of a simulation of an ecology laboratory where students can add and/or remove organisms to explore feeding relationships. The set of actions that pupils can perform includes move, eat, be eaten, be predator, etc. The Ecolab laboratory can be viewed from three different perspectives. The 'world view' shows plants and animals as they would look in the real world. The 'energy view' shows, using bar graphs, the levels of energy associated with the organisms in the Ecolab. Finally, the 'web view' is a diagrammatic representation of the eating relationships represented in the system. The curriculum is divided into nodes with different versions of the system imposing more or less control over the order in which the nodes are tackled. Previous evaluations of the Ecolab system have illustrated the benefits of challenging students and guiding, but not controlling, their learning [7] and of offering the learners help at the meta-cognitive level by making low-ability learners more aware of their help-seeking needs [9]. The success of previous Ecolab systems is thought to derive from modelling the learner's cognitive and meta-cognitive traits. By considering the learners' ability and collaborative support at interaction time, the Ecolab is capable of altering the system's reactions for individual learners. Ecolab provides help at four levels of quality: the deeper the level, the greater the control taken by the system and the less scope there is for the pupil to fail [10].

To shed some light onto the effect of motivating the learner we developed M-Ecolab as an extension of the Ecolab software to provide motivational scaffolding. Various approaches have been taken to assess the degree of motivation in learning environments. Song and Keller [4], for example, utilized motivational self-assessment to provide appropriate motivating techniques to the learner. Our approach, however, revolves around *modelling* three motivational traits identified as key in learning contexts [11]: effort, confidence and independence from the tutor. In our model, effort modelling considers quality and quantity of the actions within the software, and the persistence that learners display when facing errors. Independence is modelled considering the degree of help provided by the system. Confidence is modelled based on the degree of challenge-seeking that learners display during the interactions. The rationale for motivational modelling is that the system can react differently to learners in different states of motivation via a model of the learners' motivation, built by assessing their actions, cognitive and meta-cognitive states and relating them to the motivational variables previously described. Since the original Ecolab was based on a Vygotskyan model [7], an explicit "more able" partner has been incorporated in the M-Ecolab as a motivating element through the use of an on-screen character called Paul. We provide motivational scaffolding consisting of spoken feedback given at two times, pre- and post-activity. Pre-activity feedback is inevitable and informs the learner of the objectives of that learning node; post-activity feedback, on the other hand, offers comments to help learners reflect on their behaviour at that node. Since the system maintains motivational models for individual learners the feedback given by Paul at post-activity time is adjusted. The adjustment is underpinned by the motivational model and consists on alterations of Paul's voice tone and gestures. According to the model's perception of the learner's motivation/de-motivation Paul encourages the learner: to exert more effort, to be more independent or to become more confident. For example, if the motivational modelling determines a low state of motivation because the quality of the actions was poor, Paul's post-activity feedback states: "For the next node try to make fewer errors". Under these circumstances, Paul's face would reflect concern. For a more detailed description of M-Ecolab interactions refer to [12]. We also included a quiz as motivating element. It is available during the interaction via a button within the interface but constitutes just an option that learners can activate at will. If activated, the quiz asks questions related to the topic of food-chains. Wrong answers are not corrected but an indicator reflects the number of correct and incorrect answers that the learner has given during the interaction. Correct answers are praised; a maximum of three questions is allowed per learning node in order to prevent the learner concentrating more on the quiz than on the main learning activities.

3. Evaluating the M-Ecolab

To measure the influence of the motivational scaffolding on the learners' behaviour and to try to establish its impact in comparison to previous Ecolab assessments, an evaluation of the M-Ecolab was made in a local primary school during March 2005. We assessed students' knowledge of food webs and chains employing isomorphic pre- and post-tests experiment time. This test was also used in previous evaluations [8, 9]. Please note that the questions used in the pre- and post-tests were different from those of the quiz. The learners' *initial* motivation using the system was assessed via an adaptation for British primary schools of Harter's test [13]. We chose Harter's test as its reliability has been demonstrated and it is, arguably, the scale most widely used for measuring children's individual differences in motivation. There were 19 learners who employed M-Ecolab, 9 girls and 10 boys: all members of three fifth grade classes, aged 9-10. All participants had been exposed to the standard, non computer-based teaching of food-chains *prior* to the study. They were asked to complete the pre-test for 15 minutes and then Harter's test for a further five minutes. Two weeks later M-Ecolab was demonstrated with the use of a video-clip showing its functionality. At this point the researcher answered questions regarding the use of the software. One tablet PC loaded with M-Ecolab was provided for each learner. The students were then allowed to interact with it for 40 minutes. A week later a second interaction session took place for a further 40 minutes. Immediately after the second interaction the pupils were asked to complete the post-test. The participants were not taught about the topic of food chains *between* sessions.

4. Results

The previous evaluations of Ecolab looked at how two variations of the software affected participants' learning of feeding relationships according to the learners' ability (or skill) [8, 9]. The criterion employed to divide the sample was the students' results of their Science SAT (Standard Assessment Test – a national test used in the

UK) using a tertile split. We recognize that this method of analysis does not always provide the best approach to analyze differences [14]; however, we chose to follow this method in order to be consistent with precedent evaluations. We categorized children into 3 ability groups, see Table 1.

Table 1 Pre- and post-test scores according to ability

Ability	Pre-test score Mean (SD)	Post-test score Mean (SD)
Low (n = 6)	15.0 (6.03)	21.17 (6.18)
Average (n=9)	18.56 (4.95)	24.0 (4.03)
High (n = 4)	28.50 (5.92)	29.50 (2.08)

Motivation in the M-Ecolab

We wanted to explore the motivational development that learners experienced through their use of M-Ecolab. To that effect we analyzed students considering their motivational state both before and during the interaction. We acknowledge that the scales to assess motivation *before* (Harter's scale) and *during* (model of motivation specific to M-Ecolab) the interaction are different and that a better rationale should be used in future evaluations. Nevertheless, these two indications were combined to make four groups to analyze the effects of motivating techniques on learners (see Table 2):

- Group 1. Motivated students *before* and *during* the interaction (MM).
- Group 2. Motivated student *before* with low motivational *during* the interaction (MD).
- Group 3. De-motivated students *before* with high motivation *during* the interaction (DM).
- Group 4. De-motivated students *before* and *during* the interaction (DD).

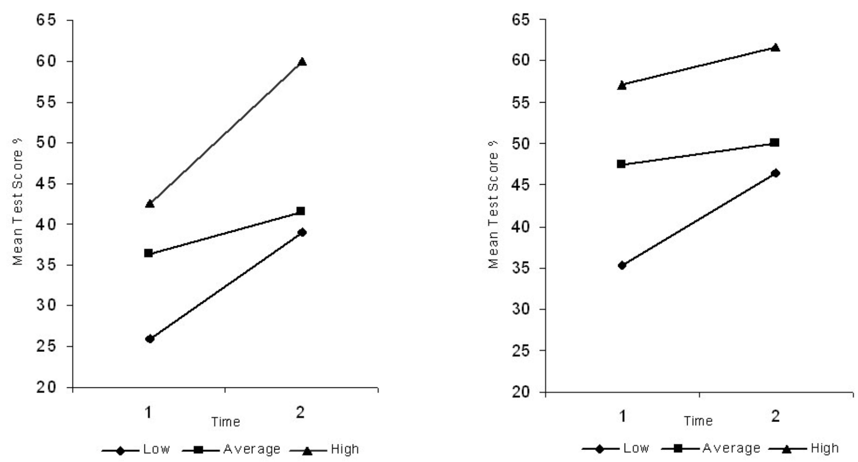
Table 2 Distribution of M-Ecolab students considering their motivational change group

Group	Population	Effort Mean (SD)	Independence Mean (SD)	Confidence Mean (SD)	Learning Gain
1	n = 6	.54 (.11)	.71 (.07)	.60 (.05)	12.87 %
2	n = 6	.38 (.09)	.42 (.09)	.65 (.14)	17.42 %
3	n = 4	.58 (.06)	.67 (.09)	.64 (.14)	40.90 %
4	n = 3	.30 (.12)	.41 (.07)	.61 (.32)	27.27 %

Table 2 reveals that the majority of students had high motivation *before* the interaction (Groups 1 and 2). Interestingly, their learning gains were the lowest for the population. By contrast, it was the students of Group 3 those with the highest percentage of learning gains. Not surprisingly members of Group 3, with three low and one average ability pupil, all had above average learning gains. We also analyzed differences in terms of the motivational variables (effort, independence and confidence) for pupils with higher learning gains (Groups 3 and 4). We found significant differences in effort ($t(5)=3.932$, $p=.011$) and independence ($t(5)=4.054$, $p=.010$) but not in their confidence. We also found that members of Group 3 *followed* the suggestions provided by Paul at post-activity feedback more than members of other groups. We speculate whether this factor could explain the differences in levels of effort and independence observed and the differences in the percentages of learning gains. The increase of motivation and learning gains observed in members of Group 3 was encouraging and led us to further investigate the interaction characteristics of learners with initial low motivation. Although the low learning gains for high motivation students is interesting, we focused our attention here on understanding the behaviours and characteristics for less motivated pupils.

Comparisons to previous evaluations

In Ecolab I [7] high ability students improved more than other abilities as we found a significant within-subjects pre- to post-test difference. In Ecolab II [9] low ability students benefited most from the meta-scaffolding provided (Figures 1a & 1b).



a. Ecolab I

b. Ecolab II

Figure 1 Ability by testing time, Ecolab 1 and Ecolab II

In M-Ecolab the situation was different as it was both average and low ability students who improved their scores significantly from pre- to post-test (see Figure 2, please note that the mean test represent percentages and not actual values as those of Table 1). One of our concerns while drawing comparisons to previous Ecolab evaluations was the difference observed, at pre-test time (T1), among children's ability at three different schools. We believe, in a similar way to [9] that, this difference is not explained by discrepancies in abilities among samples but is more likely to be an effect of shorter periods of time elapsed from the learning of the concepts of food chains in a non-computer fashion and the use of the pre-test. An analysis of variance (ANOVA) of the pre- and post-tests scores using one within-subjects variable (time: 1 = pre-test, 2 = post-test), and one between-subjects variable (ability: high, average, low) indicated the difference between the ability groups in M-Ecolab was significant ($F(2,16) = 4.022$, $R^2 = .251$, $p=.038$).

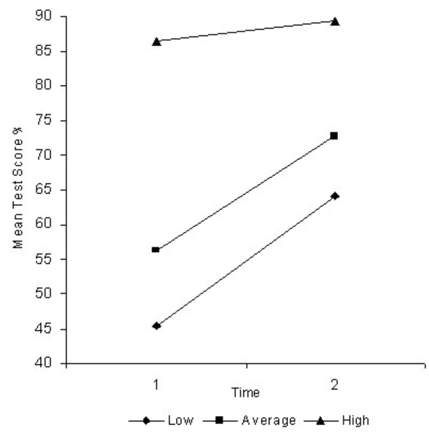


Figure 2 Ability by testing time, M-Ecolab

We will now examine the following: What were the learners' characteristics and behaviours that may have accounted for the increase in performance observed in low and average ability students? What was the type of help received by the learners? What was the impact of the motivating techniques on the learners? And how do these compare with previous Ecolab evaluations?

Nature of M-Ecolab interactions

To throw some light onto these questions we looked at the records of the interactions, maintained in log files kept for individual M-Ecolab learners. These records were examined to reveal both the *character* of the interactions and the *type of help* provided by the system. The relevance of using behaviours is that in combination with the students' ability, learning gains and motivation we can gather evidence of what might have constituted a fruitful interaction in M-Ecolab. To be consistent with previous evaluations we considered existing definitions of behaviours [8]:

- **Challenge-seeking** is an interaction trait associated with a learner's inclination to accept challenging activities. At the beginning of each learning node, Ecolab provides opportunities for children to select among 3 different levels of challenge. This behaviour was referred to as *exploration* in previous evaluations [9]. However, we believe that a more descriptive name should be used. The opposite behaviour is known as challenge-avoiding.
- **Busyness** is an interaction characteristic determined by measuring the number of actions of any type such as help request, adding or deleting organisms, etc. An above average number of actions categorized a student as busy or quiet otherwise.
- **Hopping** is a behaviour associated with a learner who switches frequently from one type of view to another. These interactions contain no or few series of repeated actions of the same type. The opposite of a hopping conduct is known as a persistent behaviour.

Because the essence of M-Ecolab was to provide motivating strategies to de-motivated students we were concerned about the degree of "distraction" that learners could have had during their interactions due to an excessive use of the quiz. To have an insight into how this affected students we have defined a new behaviour:

- The degree of **quiz-using** that students experienced during their interaction with M-Ecolab was considered. Learners who visited the quiz an above average number of times were considered quiz-seekers or quiz-avoiders otherwise.

In previous Ecolab evaluation the importance of the challenge-seeking behaviour has been highlighted [9]; it was found that this behaviour was present amongst students with above average learning gains (92% in Ecolab II, 82% in Ecolab I). However, there was a discrepancy between Ecolab I and Ecolab II regarding the composition of the groups of challenge-seekers: In the Ecolab II there was evidence that the group of challenge-seekers was composed of all three ability groups, as opposed to a majority of high ability students in Ecolab I. This discrepancy was thought to be the effect of meta-cognitive scaffolding provided by Ecolab II [9]. We analyzed whether the M-Ecolab produced the same effect and found that challenge-seeking was an important trait when motivating elements were present. 58% of students with above average learning gains, belonging to Groups 3 and 4, were challenge-seekers, see Table 3.

Table 3 Distribution of students considering their average learning gains and behaviours

	Challege-seekers n=10	Quiz-avoiders n = 10	Persisters n = 9
Students with above average learning gains n = 12	n = 7	n = 8	n = 8
Students with below average learning gains n = 7	n = 3	n = 2	n = 1

We found that students with above average learning, including both low and average ability, were not inclined to use the quiz. We also found that 67% of students with above average learning gains were persisters. Furthermore, when we combined behaviours to form duplets, we found that only 50% of learners with above average learning gains were both **quiz-avoiding** and **persisters**. This suggests an effect of motivating techniques in M-Ecolab which is different from both Ecolab I and II evaluations. In earlier studies it was found that the combination of busyness and challenge-seeking yielded better learning outcomes: 71% of Ecolab II and 70% of Ecolab students with above average learning gains had this behaviour.

Help-seeking in the M-Ecolab

Two traits of the interaction from previous Ecolab evaluations were used to denote help usage in M-Ecolab:

- Students who sought an above average quantity of help were considered to have had **lots** of help, or little otherwise.
- Similarly, pupils who requested greater levels of help were contemplated as having had **deep** help, or shallow otherwise.

The study of help provision in M-Ecolab had a particular relevance for us because in a pilot study [12], where pupils used M-Ecolab for 40 minutes, we found that the motivating techniques made an impact upon the *qualities and quantities* of help selected between two experimental group. We found that M-Ecolab learners were significantly *less* independent from the system's help as they requested greater qualities and quantities of help. Our analysis showed, however, that the findings of the pilot study were not replicated. We believe that the factor that accounts for this discrepancy is the total interaction time (40 minutes for the pilot, 80 minutes for this evaluation). It may have been the case that a longer interaction had an impact on the learners' behaviours, particularly regarding help-seeking.

Nevertheless, by analyzing the help requested by low ability pupils with above average learning gains, we found that these students used *lots and shallow help* and that average ability students with above average learning gains utilized *little and deep help*. This difference in help-seeking behaviour suggests that successful students used a very different help-seeking strategy depending on their ability.

5. Discussion

Our findings suggested that by modelling motivation and adjusting the motivational reaction initially de-motivated students significantly increased their post-test scores. We also found that low and average ability students also improved their post-test performance. However, we also found that neither initially highly motivated nor high ability students increased their post-test scores; we are aware, however, that this result could be due to a "ceiling effect" (see Figure 2). In order to find the specific causes of learning gains in de-motivated, and in low and average ability students we analyzed the learners' interactions following the approach taken by Luckin [8], and catalogued students according to behaviours. We noted that our results are consistent with previous findings [9] in the sense that *seeking for challenge* is a characteristic of learners with higher learning gains. Further analyses suggested that the combination of behaviours that yielded better learning gains for low and average ability students was that of being *quiz-avoiding and a persister* as opposed to being busy and challenge-seeker in previous Ecolab evaluations. Regarding help-seeking, we found that successful students used very different strategies depending on their ability: low ability students used lots and shallow help whereas average ability students utilized little and deep help.

Regarding initially de-motivated learners, we analyzed whether successful students (belonging to Group 3 in Table 2) varied their effort, independence or confidence during the interaction. We found that students with above average learning gains had significantly higher degrees of effort ($t(5) = 3.932$, $p = .011$) and independence ($t(5) = 4.054$, $p = .01$). Interestingly, we found that successful students *explicitly followed* the post-activity feedback provided by an on-screen character who adjusted his tone of voice and facial expressions considering individual learners' motivation. Curiously, initially motivated students did not vary their behaviour much during the interaction tending to have similar values for effort, independence and confidence during 80 minutes of interaction. We believe that the presentation of motivating techniques to motivated learners was not beneficial. This is consistent with Keller's [15] suggestions that motivating techniques should be used with care for high motivation students.

These results have suggested an effect on learning of the motivating techniques; more importantly, these effects were different depending on the students' ability and motivation. These results have also suggested an important influence of spoken feedback (adjusted considering the learners' motivational state) at post-activity time. However, we acknowledge that these results have been derived from a very small sample (n=19). We also acknowledge that our motivational modelling needs further development: we intended it to present motivating strategies to de-motivated learners only and not to all the sample as was the case. We also think that adapting the feedback and character's reactions, in conjunction with a quiz, constitute only a first step for the study of motivating techniques in ITS's and that a wider range of possibilities could be also considered in future research. But despite these drawbacks we believe that the findings reflect an interesting effect of motivating de-motivated or low and average ability students. These results also suggest general guidelines that could be used to improved students' motivation in ITS's. The results should be interpreted only as an indication of the effects of motivating learners in ITS's and as general pointers for future research on motivation.

Can we be motivated to learn? Although the topic of motivation in tutoring systems is a vast field involving both affective and cognitive states, we believe that the design of ITS's could include motivating elements that might be conducive of learning particularly for low ability students. If our ITS's are to motivate students we need to provide a means of recognizing the causes of de-motivation, particularly lack of effort or excess of dependency on the system's help, and encourage learners to improve these behaviours.

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