Designing Adaptive Motivational Scaffolding for a Tutoring System

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Introduction

Attribution Theory (Weiner 1990) and Goal Orientation Theory (Ames 1990) provide human teachers with useful guidelines to help them understand students' motivation and *personalize* their choice of educational activities. Such theories can assist teachers by informing the way they may interact with students in real class settings. However, it is less obvious how these theories can aid the development of motivationally-aware educational technology. One of the strengths of educational technology, for example intelligent tutoring systems, is the use of learner models to adapt the learning activities to the student's current abilities and needs. This adaptation has provided some degree of efficiency tailoring in educational content delivery but the resulting activities are not, necessarily, motivating for students.

The focus of this chapter is the application of the concept of personalization in tutoring systems (user modeling plus scaffolding) to implement concepts taken from theories of motivation in order to develop a motivationally-aware tutoring system. The underlying reason for motivational personalization is that matching the delivery of learning material to students' motivation (or de-motivation) should improve their experience and, arguably, also their learning. Ecolab II is the intelligent tutoring system chosen to experiment with motivational scaffolding. It was selected because its underlying principles of adaptation are also applicable at a motivational level. Ecolab II is a system that is inspired by the work of Vygotsky in the sense that it models the learner's Zone of Proximal Development in order to scaffold the learning process, particularly by suggesting help and adapting task-challenge levels to individual students. The idea behind Ecolab II is to personalize the learning process by suggesting increasingly complex activities or different levels of help. The result can be seen as a virtual more able partner who provides activities that are part of the students' education but slightly beyond his or her independent ability (Luckin and du Boulay 1999).

There are two difficulties in working with learner's motivation in computer-based settings, the first is how to detect varying states of motivation and the second is how to remediate negative states. The problem of detection has been considered for other tutoring systems, see for example (de Vicente and Pain 1999) and in the Ecolab II (Rebolledo-Mendez 2003). This chapter deals with the second problem (remediation) and presents the design process for the motivational scaffolding of the same tutoring system[1]. This chapter does not address issues such as affect (Burleson and Picard 2004) or emotions but focuses on how to motivate learners considering the theories of motivation presented in the Background Section. Designers of motivational scaffolding, it is hoped, may benefit from the design process presented in this chapter as it describes how motivation was conceptualized and then made explicit in the tutoring system. The chapter also presents the result of an initial evaluation suggesting a positive influence of the motivating techniques.

Background

Motivation is a term that has been understood differently by different researchers. If one considers motivation to be concerned with what induces a student to learn then the differences in definition relate to the perceived cause of that inducement. Some researchers believe that the cause is external and based on stimulus-response connections; others believe that it is internal and originating in beliefs,

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[1] There is evidence suggesting the problem of remediation of demotivation is also true among teachers (Balaam 2007).

thoughts or objectives. Educational technology has borrowed concepts from some theories of motivation to design tutoring systems that consider motivation. One of the first examples of a tutoring system addressing the issue of motivational detection was MORE (del Soldato and du Boulay 1996). Other works which consider motivation include the Genetics System (Song and Keller 2001) where Keller's (1983) model of motivation called Attention Relevance Confidence and Satisfaction (ARCS for short) was implemented, the Virtual Factory Teaching System (Qu and Johnson 2005) which utilizes biometrics based on the learners' gaze to model motivation, and the My Pet Our Pet system (Chen et al. 2005) which motivates learners to collaborate in computer mediated instruction. Corresponding to the richness and diversity of motivational strategies, their implementation in tutoring systems reflects the designers' understanding of motivation. For the purposes of this chapter, motivation is understood as the student's desire to expend effort in the pursuit of learning activities while seeking less help and greater task challenges (Rebolledo-Mendez 2003). For an historical perspective on the study of motivation in education please refer to (Weiner 1990).

This chapter starts with the notion that motivation is linked to the desire for performing learning activities based on acting as a response to expectancies and values (Rotter 1954). Expectancy is referred to as the state of mind that triggers different types of behaviors in individuals in order to achieve goals. These behaviors are regulated by the expectancy of the reward and by the value of the reward. Expectancy shifts were typical when people's performance was attributed to skill**.** As such, performance is controllable and expectancy increments may be expected after success; when performance is not controllable, expectancy decrements may be expected after failure (Rotter 1954). Based on the idea of expectancy, other concepts entered motivational research. For example, an extension to the idea of expectations, specific behaviors associated with expectancies can be defined (Cantor 1990): high achievers display an optimistic behavior to reinforce their success whereas defensive pessimists expect to do poorly or anticipate a variety of negative scenarios. Helplessness is another behavior that is used to explain lack of motivation in students who often do not exert enough effort:

learned helplessness is due to the student's belief that success is out of their control (Dweck 1975).

Achievement theory (Atkinson 1964) considers the notion of triumph in undertaking a goal: individuals with higher needs for recognition prefer tasks of intermediate difficulty. Achievement theory evolved into Goal Theory (Ames 1990) which studies the types of goals and their impact on learning. Goal theory combines the concepts of involvement, rewards and social comparisons as indicators of success and ability. Intrinsic and extrinsic motivation are other concepts that might explain the influence of motivation on learning (Deci 1975; Sansone and Harackiewicz 2000). Extrinsic motivation prompts behaviors that arise as the direct influence of externally administered rewards (pay, possessions, prestige, positive feedback for example). In contrast intrinsic motivation is believed to exist when the behavior displayed is inspired by learning for its own sake rather than to obtain material or social reinforcement. The term intrinsic implies internal, psychological needs that reinforce students' behaviors (Sansone and Harackiewicz 2000). Key intrinsic motivators include responsibility, challenge, achievement, variety and advancement opportunity.

An interesting angle on motivation incorporates the idea of positive feedback as a kind of retribution or praise (Deci 1975). A series of studies showed that humans perceive positive feedback after an easy task as denoting low-ability on their part (Deci 1975). However, positive feedback after a difficult task was considered as very rewarding. Other studies show the effects of feedback interventions as altering the person's motivational state depending on their source: results suggested that people feel less intimidated by computer feedback than they are by human feedback (Kluger and de Nisi 1996).

There are also practical approaches to defining motivation, such as the ARCS model (Keller 1983) mentioned before. In ARCS, motivation is regarded as being influenced by four major factors: Attention, Relevance, Confidence and Satisfaction. Attention is the first requirement to achieve motivation; it has to be obtained and appropriately directed by cues that engage the student in the learning activity. Acquiring attention is often not difficult but the challenge is in sustaining it during the learning process. Attention can be subdivided into the visual and the cognitive, having curiosity as its main component. Relevance is the second requirement to achieve motivation. Tutors must demonstrate the relevance of the material so that the students perceive a degree of meaningfulness in what is being taught. Even if the tutor improves the learners' attention and sense of relevance, motivation may not be achieved due to too little or too much confidence, which could be related to the learner's expectancy of success. Tutors should be able to detect and correct any excess or lack of confidence through the use of tailored strategies. By doing so students will become more realistic about what they can learn given the context of the lesson. Finally, satisfaction must be created in the learner to give the learning a sense of fulfillment. The provision of rewards should also be included in instructional design to achieve greater degrees of satisfaction. As a consequence, to achieve a more effective learning experience, instruction needs to place a special emphasis on optimizing the four factors of the model. Motivational diagnosis demands that the teacher constantly assesses any change in these variables, which could be the basis to trigger or withdraw motivational support. A practical applications of the ARCS model in a tutoring system is provided by Song and Keller (2001).

This chapter addresses the design process pertaining to the inclusion of motivational elements in the Ecolab II, an intelligent tutoring system for Ecology. This process involved the application of learner-centered design techniques to define motivational scaffolding for Ecolab II. We adopted the 'prototypes for rapid visualization' approach (Curtis and Vertelney 1990), in which different prototypes were designed, tested and rebuilt, eventually leading to the final version. The methodology of rapid visualization does not define a predetermined number of cycles before a final user interface is created although the starting point is always an analysis of user needs. Because of the evolutionary nature of this model, the process is very flexible and allows the participation of learners during some or all of the stages of designing and testing. The methodology emphasizes that the system's designer should use the results of the tests to build an improved version of the previous prototype. The following section describes the design process including the conception and testing of motivating elements for the tutoring system.

Developing scaffolding for a tutoring system

The tutoring system chosen to incorporate motivational scaffolding is called Ecolab II. This tutoring system is based on the Ecolab system (Luckin and du Boulay 1999), an implementation of a Vygotskyan-inspired design framework. This includes a learner model that records the actions successfully completed by each learner and the amount of system assistance that the learner required in order to achieve that success. The design of this learner model is based upon an interpretation of Vygotsky's Zone of Proximal Development (ZPD). The design framework also includes an embodiment of a virtual more able partner that provides help and challenges the learner to complete slightly more difficult learning options during the learning process (Luckin and du Boulay 1999). Ecolab II teaches the concepts of food webs and food chains to children aged 10 and 11. It provides a flexible environment offering the student different perspectives on ecological concepts as well as increasingly complex activities organized in a learning curriculum. The activities are adjustable to the students' ability and challenge-taking preferences. To support this level of personalization, Ecolab II maintains a learner model which quantifies the student's Zone of Proximal Development (ZPD), indicating which areas of the curriculum are beyond what the student can do alone but are achievable when the system, acting as the more able partner, provides appropriate support. The learner model provides Ecolab II with elements to take decisions about how much support he or she needs to ensure that the learner is successful when interacting with activities within the curriculum. The decisions taken by Ecolab II are based on the learner model and can be thought of as those of a virtual more able partner offering the learner activities slightly beyond her current understanding but within her capacity. It was considered important that the inclusion of motivational scaffolding should be consistent with the Vygotskyan nature of Ecolab II and should provide motivational help consisting of varying motivational support based on a motivational model of the learner. The rationale for personalizing motivational help is outlined in a previous paper (Rebolledo-Mendez 2003).

The design process that led to the development of M-Ecolab (motivational Ecolab) involved the application of learner-centered design techniques and the development of 'prototypes for rapid visualization' to design motivating elements to build the motivational scaffolding for Ecolab II. Five prototypes were designed, tested and rebuilt in 5 phases, eventually leading to the final version of the tutoring system.

Phase 1: The effects of feedback interventions in Ecolab II

An exploratory learner-centered study was carried out to assess the influence of feedback interventions (Deci 1975; Kluger and de Nisi 1996) in the target tutoring system. The purpose was to see the effects of the wording of feedback on different learners. There were two male participants aged 9, both Year 4 (fourth grade) students. The two participants each experienced a different version of Ecolab II's help messages: one with flattering-feedback and the other with factual-feedback. The help messages were developed considering the following criteria: a) the flattering feedback included messages containing praise and favorable words referring to the student in the first person; b) the factual feedback included help messages containing words describing facts using impersonal words and no praise was given. To measure motivation a self-assessment questionnaire pre-test was constructed based on Keller's (1983) theory of motivation. The learners were then asked to interact with Ecolab II for as long as they wanted. After the interaction, a post-test was administered to give an indication of the degree of satisfaction with the system.

Considering the answers in the pre-test, one of the participants showed a clear interest in the topic of food-chains and webs and expressed his desire to become a zoo keeper or a safari rider; he was particularly interested in animals' eating habits. This participant happened to be assigned to the factual feedback condition. The other participant did not show any interest towards science; he happened to be in the flattering feedback condition. An analysis of the interactions showed that both children spent the same amount of time interacting with Ecolab II. However, the child in the factual feedback condition, being motivated towards food chains, completed a considerably larger number of learning activities than the other participant. An analysis of the post-tests showed that the student interacting with the factual version of M-Ecolab was more interested, considering the number of questions related to Ecolab II that were answered. Although it is not possible to draw firm conclusions from such a small study, it explored the nature of motivating feedback and its implications for less motivated learners.

Phase 2: Developing a quiz and a crossword puzzle

It was decided to try out other elements that could arouse students' curiosity and interest in the learning material presented in Ecolab II. A quiz and a crossword puzzle were thought of as elements that might arouse curiosity and interest, in line with Keller's (1983) suggestions on how to increase learner's attention, the first major variable in the ARCS model (Keller 1983). Low-tech materials were used for the development of the prototypes; the questions for the quiz and the words for the crossword were obtained from the domain of Ecolab II's curriculum. The evaluation was intended to uncover usability problems using established human factors principles. The participants in this evaluation were six usability experts and the materials used consisted of the prototypes presented via slides. The procedure involved asking the evaluators to express their opinions with written comments about the prototypes. The results revealed problems with several aspects of the designs including the lack of rules to operate both the quiz and the crossword puzzle, which were familiar to the evaluators but not necessarily to the children. There was also a recommendation to personalize the quiz by referring to learners by name and also to adjust the difficulty of the questions to the degree of challenge that learners were willing to take, making use of one of the existing features of Ecolab II. The interface envisaged for the quiz needed to be more explanatory and it was suggested the system could provide explanations for different elements when the mouse pointer was on them. The crossword did not need to have an elaborated description as it was thought that children would be familiar with it. The interface for the crossword was intuitive but the definition of its components (vertical and horizontal words) used complicated words that, it was thought, children would find difficult to grasp. The final recommendation was that both prototypes needed an exit button that would allow the learners to leave the facilities whenever they wished.

Phase 3: An improved quiz and crossword

Phase 2 provided useful results but it was still not clear whether the quiz and crossword would motivate Ecolab II learners. To find out, it was necessary to have input from learners themselves to produce a more robust prototype. A participatory design setting was devised in which learners and designers collaborated to create a newer prototype. The study used a combination of high- and low-tech materials including two card-based games. The low-tech card-based games consisted of color printouts of the quiz and crosswords prototypes as described earlier that worked in conjunction with a computer with Ecolab II running. The new quiz included the same questions as in the previous version with three possible answers to choose from. An example question is “In the Ecolab, can you find out what eats caterpillars?” with a set of possible answers such as voles, toads or thrushes. For the crossword puzzle a new set of words was developed, the new words were expected to be understandable for the target population.

The aim of evaluating the new quiz and crossword was to find out whether these were suitable to work in conjunction with Ecolab II and whether learners thought these materials were suitable for Ecolab II. The participants were two boys and one girl aged between 9 and 11. They were asked to interact with both Ecolab II and the low-tech prototypes. The participants were taught how to interact with Ecolab II and told what the software was intended for. Five minutes free-play time was allowed after instruction. Once the learners were comfortable with the software, they were informed of the objectives of this experiment and were asked to play with the card-based quiz and crossword games described earlier. Participants were encouraged to suggest improvements or new games to make Ecolab II more fun. The interaction with the low-tech prototypes and Ecolab II continued for thirty minutes while the participants were talking aloud. The results of this experiment suggested the wording of both the quiz and the crossword was appropriate. It was also evident that the participants did not spend much time reading the feedback provided by the software and preferred to continue exploring the software by themselves. According to the learners' later comments, the prototypes were experienced as somewhat detached from Ecolab II both physically and conceptually and consequently did not reflect what was being taught. The participants suggested that a story would be preferred to isolated games such as the crossword and quiz. When asked about the nature of the narrative, the participants recommended that a plot could be integrated and emphasized that the use of characters would make it 'more fun'. The idea of the character was interesting as it was thought it could be employed to create expectations in learners (Rotter 1954) via spoken feedback. Another possibility was to use the character as a mechanism to deliver varying motivational feedback that could be matched to the perceived state of motivation. Even though the number of participants was very limited, the suggestions were taken into account.

Phase 4: Designing a narrative

Narrative Centred Informant Design (Waraich 2002) was considered in order to design the story for Ecolab II. A strong requirement for the new narrative was to preserve Ecolab II's interface, user model and metaphor and to include either the quiz or the crossword puzzle. The existing features of Ecolab II could be used to model motivation (Rebolledo-Mendez 2003) and provide a platform through which to display the story. To inform the design of the narrative, two 9-11 year old learners, one boy and one girl, were interviewed. They were asked to suggest characters and a story for a virtual ecology laboratory. Their answers were video taped. Conversations with the learners revealed that they were enthusiastic about a treasure-hunting story for Ecolab II. They also suggested help could be provided by the character when a difficult task was given. To keep consistent with the Vygotskyan approach of Ecolab II, a virtual partially embodied more able partner was considered. This character could convey motivating spoken and domain specific feedback, adapting its tone by considering the learner model (Rebolledo-Mendez 2003) maintained by the tutoring system. The learners showed a preference for cartoon-like characters to maintain consistency with the look of Ecolab II. For the learners, one important trait of the character would be its ability to change its gestures and tone of voice to match events in Ecolab II. One feature that could not be defined at this stage was the character's spoken feedback. This was not a simple task as the feedback could cause an important change in the student's motivation.

Considering Kluger & de Nisi's (1996) idea that computer-based feedback could be less intimidating, it was decided that the rationale for the characters' changes of intonation would be determined by changes in the learner's motivation. By doing this, the characters' believability could be increased, which might lead to improving motivational states in the students. For example, by making the character say the phrase "try to put more effort" (in a "worried" tone), the learner would react differently than if the character said the same phrase in a "happy" tone. Considering the young learners' suggestions, the character (nicknamed Paul) would use "kid's language" and two tones (worried and normal, see Figure 1).

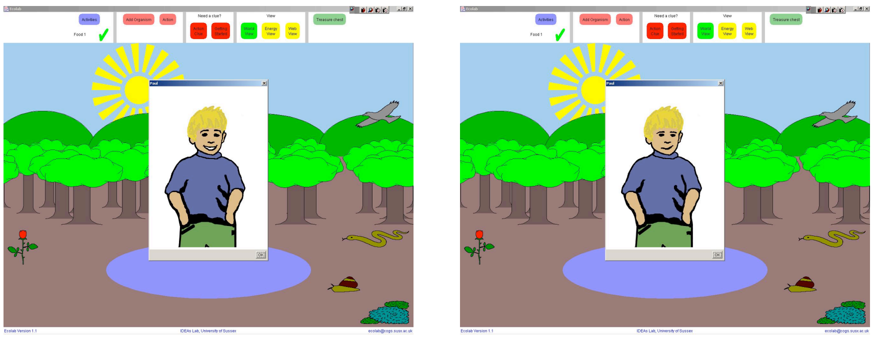

Figure 1 Facial expression variations

If the learner's motivation were high, the intonation would be happy, else it would be worried. The presented feedback would consider the assumed cause of de-motivation and the context of the learning activities. To keep consistency with Ecolab II activities, the character would produce feedback at two points: before and after an activity. Pre-activity feedback provided variations of tone of voice and facial expressions considering 1) the student's motivation and 2) the correctness of her responses in the previous activity. Post-activity feedback was only given when the student had low motivation during the activity, see Table 1.

Table 1. Variations of Paul's feedback

	Pre-activity feedback		Post-activity feedback	
Motivation	Tone of voice	Facial expression	Tone of voice	Facial expression
Low	Normal	Normal	Worried	Worried
High	Normal	Normal	n/a	n/a

To evaluate this prototype, low-tech materials and Ecolab II were used in a Wizard of Oz style study. The participants were five 9-11 year-olds, one girl and four boys. They all agreed to take part in the study and worked individually. The setting for this new study involved individual learners interacting concurrently with two computers: one with Ecolab II and the other with the narrative and the character presented using Microsoft's Power Point. In this setting, one researcher (the wizard) could see the students' actions in Ecolab II in an adjacent room and the assessment of his/her motivation using a model of motivation (Rebolledo-Mendez 2003). The information provided by the model allowed the wizard to control the spoken feedback provided by the character. Examples of spoken feedback included: "Be bold and take more challenge" or "Try to use less help". At the end of the interaction individual learners were interviewed.

An analysis of the learner's reactions, in conjunction with the perceptions of the motivational states recorded on the wizard's computer provided indications about the nature of the motivational reactions for Ecolab II: 1) it was easy for learners to ignore written feedback; instead they tended to focus on spoken feedback; 2) the content of the spoken feedback in the prototype was out of sync with the actions and inconsistent with the learning activities; 3) the participants unanimously liked the cartoon-like of the character; 4) the participants agreed that Paul's voice was unclear and difficult to understand. The results suggested that less motivated students were particularly enthusiastic about the narrative and perceived the characters as being very useful in providing guidance during the interaction as well as being helpful and empathetic.

Phase 5: M-Ecolab takes shape

The findings in the previous phase signaled specific changes. Given that participants tended to focus on the spoken feedback, they could be directed by the character's instructions. Paul's voice needed to be clearer. The motivation model as presented in Rebolledo-Mendez (2003) would automatically detect motivation and underpin the behavior of Paul in the context of M-Ecolab. Automatic detection of the degree of motivation was made by measuring problem-solving effort, number and type of help requests and the degree of task-challenge chosen. Learners were prompted by Ecolab II to select among three levels of challenge and four levels of help (Luckin and du Boulay 1999). The idea to integrate the motivation model and the motivation reactions by Paul was in order to offer personalized motivational techniques to the learners. If the learner's motivation was low at the end of an activity, post-activity feedback would be provided using a worried tone (see Table 1). The content of the spoken feedback provided by Paul was related to the perceived symptom of the de-motivation, namely lack of effort, over-dependence on the tutor's help or unwillingness to take on challenging activities. For example, if the symptom was lack of independence, Paul would say "*for the next activity try to use less help*"; another example for lack of confidence is: "*be bold and take a greater challenge*".

To test the integration of the motivation modeler and the character a new evaluation was designed to analyze its effects. This study adopted a between-subjects design comparing the original Ecolab II with M-Ecolab that had gone through the enhancement process described above. The students' domain knowledge about food webs and food chains was measured pre and post using the same test as in previous studies of Ecolab II (Luckin and du Boulay 1999). The test consists of 11 questions and an accompanying sheet depicting a small food chain. The questions consist of a mixture of open-ended, multiple choice and drawing instructions which are marked 1 for tentative knowledge demonstrated, 2 for some knowledge demonstrated and 3 for firm knowledge demonstrated. Because of this marking scheme the maximum possible score was 33 and the minimum score was 0 (Luckin and du Boulay 1999). The students' ability was measured using the National Curriculum Assessment (referred to colloquially as SAT) results in Science for the previous year. The SAT's were used to assess students' knowledge in England and were divided into Key Stages. For Key Stage 2 (11 year old) students were assessed in English, Mathematics and Science. Motivation was measured via an adaptation of the self-report scale of intrinsic versus extrinsic orientations in the classroom (Harter 1981). All these measurements were conducted before the interaction, immediately after the interaction and again two weeks after the interaction. The participants (n=29) were students from two Year Five classes in a semi-rural primary (elementary) school in Horsham, England with an average age of 9.3 years. None of them had been involved in the previous design studies. The students used tablet PCs with either Ecolab II or M-Ecolab and were allowed to interact with the software for 40 minutes.

Table 2 Descriptive statistics for the Ecology test scores at three points of the interaction

	Control (n=10)	Experimental (n=19)
Ecology Pre-test	16.70 (5.208)	20.16 (5.65)
Ecology Post-test	17.60 (3.718)	24.95 (4.129)
Delayed Ecology post-test	20.60 (5.641)	26.39 (3.987)

To assess the effects on learning (see Table 2) with the motivation-aware M-Ecolab, a set of statistical tests was used. In what follows we note that the cell sizes are small so the results need to be treated with care. We report only those that were of interest for the investigation of the effects of M-Ecolab. Two between groups t-tests considering ability and pre-test domain knowledge showed no significant differences suggesting homogeneity. At post-test, however, results showed the students using M-Ecolab had significantly higher scores in the domain knowledge test than students in the Ecolab II condition ($p < 0.001$). Similarly, a comparison for delayed post-test showed that M-Ecolab students had significantly higher scores than Ecolab II students ($p < 0.01$).

By using the learners' motivational state prior to the interaction, between-subjects analyses revealed that the control and experimental groups were not statistically different in their initial motivation towards Science (see Table 3), suggesting homogeneity. The scores of the Ecology post-test indicated that less-motivated learners (i.e those whose scores on Harter's test were below average) in the experimental condition had significantly higher scores than their counterparts in the control group (n=7) (t(13)=-2.280, p<.05). Likewise, more-motivated students under the experimental condition had significantly higher scores in the post-test than those in the control condition (n=3) (t(12)=-5.050, p<.001).

Table 3 Descriptive statistics for learning test scores considering learner motivation before the interaction

	Ecology Pre-test	Ecology Post-test	Delayed Ecology post-test
Control, less-motivated (n=7)	16.86 (3.485)	18.43 (3.910)	21.71 (6.047)
Experimental, less-motivated (n=8)	18.50 (6.928)	23.75 (5.203)	26.13 (4.086)
Control, motivated, Ecolab II (n=3)	16.33 (9.238)	15.67 (2.887)	18.00 (4.359)
Experimental, motivated (n=11)	21.36 (4.478)	25.82 (3.125)	26.60 (4.115)

Analyses of the changes of motivation during the interaction were performed using the student's motivational state during the interaction as recorded by M-Ecolab's model of motivation. The results of between-subject analyses revealed that there was no significant difference for effort or confidence between Ecolab II and M-Ecolab II users but there was a significant difference (t(25) = 2.069, p<.05) in the independence component. This result indicated that Ecolab II students requested less help from the system than M-Ecolab learners did (Rebolledo Mendez et al. 2005). This result suggests that M-Ecolab students might have been prompted to request more help by

Paul. From a motivational point of view, this result might indicate a greater degree of engagement, which was the intended purpose of the motivational scaffolding. However, this result might also indicate a greater level of dependence on the system help and, from a non-motivational point of view, it suggests students might have fallen into a kind of gaming the system behavior (Baker et al. 2008). Because there were significant differences in the scores of the Ecology test there is an indication that the help-seeking behavior could have been beneficial for the students. However, future studies might shed light onto this particular behavior. These results can only show interesting trends since the sample was very small. Future evaluation might throw more light onto these trends and the nature of motivational scaffolding in M-Ecolab.

Summary

This chapter has presented an example of the way in which the influence of theoretical concepts can shape the nature of motivational scaffolding. The development of the final prototype progressed via a series of mock-ups that gradually led to the definition of a narrative-supported environment within which different motivational elements were framed. The design methodology adopted in this research paved the way for the creation of a new motivationally aware tutoring system called M-Ecolab. An initial evaluation of the final version of the prototype (Phase 5 of the design) produced useful information particularly related to the type of behavior students displayed in the presence of motivational scaffolding: it seems students benefitted by making numerous help requests.

There are two main conclusions derived from the design process itself. The first is that the methodology used for the design proved particularly suitable since constant small evaluations of the prototypes helped identify potential errors at early stages, in this case details of the use of a puzzle and a crossword. The technique also allowed the inclusion of many elements taken directly from theoretical concepts. In particular the theoretical concepts that have informed the design of the motivational scaffolding include: 1) Rotter's (1954) idea of expectancy, expressed through the messages delivered to the students by Paul; 2) Deci's (1975) and Klueger and Addler's (1993) concepts related to spoken feedback and its delivery; 3) Keller's (1983) strategies to increase attention (including attractive elements on the environment encompassing the look and sounds of the character) and relevance (providing a meaningful and guided interaction with the tutoring system). There were other elements that have not been included but could be incorporated in future versions of M-Ecolab such as extrinsic motivators (rewards in the form of points or stars) or an exploration of intrinsic motivators.

The second conclusion of these studies is that motivation is an important factor and could improve students' learning in a motivationally-aware tutoring system. The results presented here are preliminary and a larger sample should be tested in subsequent evaluations. One interesting finding is that the motivation strategies as implemented in M-Ecolab prompted students to display the sort of help-seeking behavior that brought about better learning results. In particular, M-Ecolab students displayed a behavior which was conducive of better learning gains but underpinned by significantly more dependence on the tutor. This behavior may correspond to a gaming the system variant associated with better learning gains as defined by Baker and colleagues (2008). Future studies will allow the collection of more volumes of data and the application of educational data mining techniques to examine whether this behavior is in fact positive gaming the system behavior and whether the type of motivational scaffolding in M-Ecolab prompts learners to behave this way. Data mining techniques might also be used to study whether other behaviors of interest, such as Cantor's (1990) *high achievers* or *defensive pessimistic* are present. It would also be interesting to further study Ames' (1990) goal orientation profiles and whether they can be detected in M-Ecolab, in a similar fashion to the goal-orientated work of Harris et al. (2009) and Martinez-Miron and colleagues (2005).

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