Do school students learn more about the environment from a system dynamics model by themselves or with a partner?

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Abstract

As part of the first author's PhD project, year 9 and 10 students were given a system dynamics model of the impacts of visitors on a National Park. The students were given a pre- and post-test to determine whether their knowledge of the environment changed. Students were randomly assigned to either the individual learning condition (students interrogated the model as individuals) or the collaborative learning condition (students interrogated the model with one other student). There was a significant increase in the environmental knowledge score for those students in the collaborative learning condition, but not in the individual learning condition. The implications of this finding for the use of system dynamics models in educational settings are discussed.

Introduction

Despite the literature that says that learning by modelling is an important method of learning, there are few empirical studies of the success of modelling in science classrooms (see for example Stylianidou, Boohan, & Ogborn, 2004). In particular, there is little empirical data to support the claim that system dynamics modelling is a valuable educational tool. Instead, case studies and anecdotal accounts from teachers who have used such models are available on the web (Ragan, 1999; Verona, Ragan, Shaffer, & Trout, 2001). Other studies have raised areas for further investigation. Studies investigating the effect of systems thinking interventions on participants' mental models (Doyle, 1997), the effect of systems modelling on the development of higher cognitive skills (Jonassen, 2003) and general learning effectiveness (Spector, 2000) are needed.

This study aims to investigate the use of a system dynamics model (SDM) as an instructional tool to understand a *complex socio-environmental system* (a socio-environmental system is one that incorporates society's use of, or human impact on, the environment). The system that was used in this study was visitor impact in a National Park. In this paper, we will examine cooperative learning as one strategy to encourage the acquisition of knowledge in the areas of the nature and function of ecosystems, how they are related, and the impact of people on environments. Davies (2002) suggested that one of the features of a simulation that was important for student engagement was allowing for cooperative learning, prompting the investigation of collaborative learning in this study. Some studies have shown that both model building exercises and learning with models can promote systems thinking, improve learning outcomes and student attitude toward the class (Friedman & McMillian Culp, 2001; Kiboss, Ndirangu, & Wekesa, 2004; Kurtz dos Santos, Thielo, & Kleer, 1997). Due to time limitations, it was decided that students would participate in a learning-with-models activity.

System dynamics modelling was chosen as an appropriate modelling tool to represent this socio-environmental system for a number of reasons. System dynamics modelling requires higher level cognitive skills than those often addressed by computer-based learning (Jonassen, 2000). Simulation models have been used successfully in physics where improvements were found in students' achievement, problem solving skills, and overall understanding of the concepts (Jimoyiannis & Komis, 2001). However, there has not been agreement in the literature on this success (de Jong & van Joolingen, 1998; Hopson, Simms, & Knezek, 2001/2002). Reasons for poor results include: under utilisation of the features available; different types of learners not accounted for; and an inability to assess individual learners due to poor experimental design (de Jong & van Joolingen, 1998). Generally, the skills required to fully participate in discovery learning are the ability to generate a hypothesis, applying a systematic and planning process, and the use of high-quality heuristics for experimentation (de Jong & van Joolingen, 1998). Of those studies that did test individual measures, certain characteristics typified successful learning outcomes. They are direct access to domain information, students receiving assignments, and the availability of a learning environment that allows model progression (de Jong & van Joolingen, 1998).

Cooperative learning can be contrasted to collaborative learning because "cooperation only requires that learners work together, each learner completing a part of the task, rather than negotiating with others about all aspects of the task, as is necessary in collaboration" (Beatty & Nunan, 2004, p. 166). Often, a group of students working together at a single computer encourages collaboration because not everyone can have control of their tasks (Beatty & Nunan, 2004). Cooperative learning can be an effective learning environment, although some differences have been found in the way that male and female students work in groups (Edwards, Coddington, & Caterina, 1997). Studies have found that students in cooperative learning groups out performed individual learners in a biology subject (Singhanayok & Hooper, 1998). Cooperative learning encourages interaction with the tool (Singhanayok & Hooper, 1998); supports a range of learning styles (Wang, Hinn, & Kanfer, 2001); and allows group members to explain concepts to each other (Kramarski, 2004), which is a metacognitive strategy.

This paper will outline the results of one part of a larger study conducted by the first author as part of her PhD project. A description of the model will be given, followed by a description of the sample and instruments used. Finally the results and discussion will address the key finding of the comparison of the individual and collaborative learning environments, and implications for the use of SDMs in educational settings will be discussed.

Methods

The SDM was developed between December 2005 and January 2006. The SDM was built using STELLA™. STELLA™ has been used in a variety of both instructional and experimental or explorational studies (for example, (Davies, 2002)). The model shows visitor usage of a National Park (based on real data of the number of visitors per day

(Davison, 2000)) and the possible effects that this can have on the ecosystem. The model used in this study showed a National Park picnic area used by visitors for seven consecutive days (see Figure 1). Each day has a unique pattern of usage. As visitors leave the park, they put one piece of rubbish each into the rubbish bin. Half of the rubbish left is organic rubbish and the other half is inorganic. The garbage person comes at the same time every day to collect the rubbish. If organic rubbish is left in the rubbish bins at the end of the day, then rats eat half of it and the other half enters a process of decomposition. The decomposition process takes three days, after which the organic waste becomes additional nutrients in the environment. Graphs on the screen used by students to experiment with the model monitor the amount of waste accumulating in the park and the additional nutrients in the environment (Figure 2). Students are able to interact with both models: the time the person comes to collect the garbage (5pm, 5:30pm, 6pm, 6:30pm, 7pm, or 7:30pm); the proportion of garbage collected (90%, 95% or 100%); and the number of pieces of rubbish per person (1, 2, 3, or 4) are able to be altered by students.

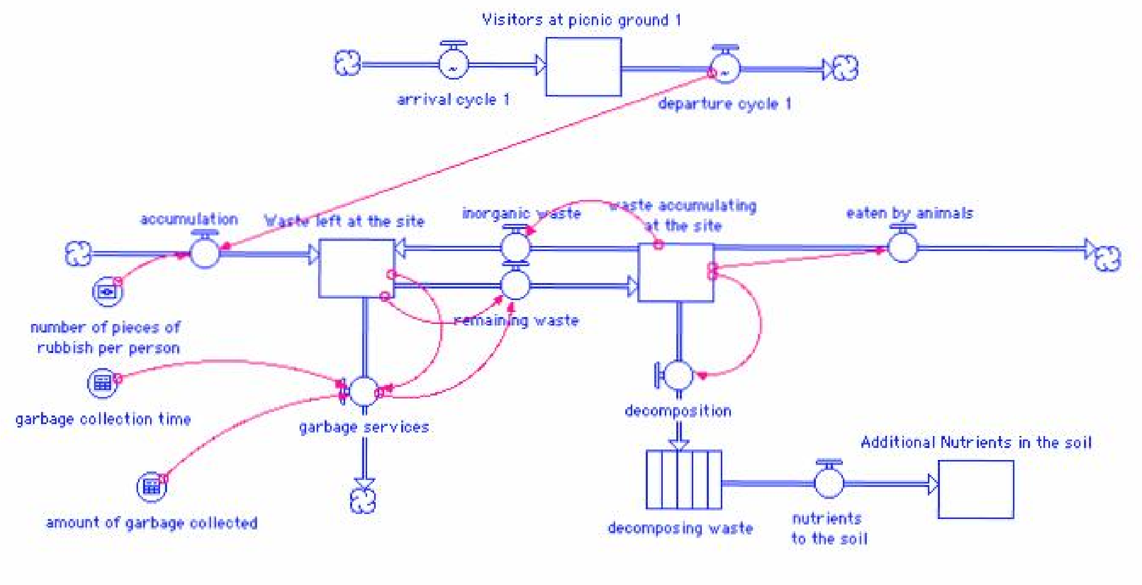

Figure 1: Stella™ model designed for this study

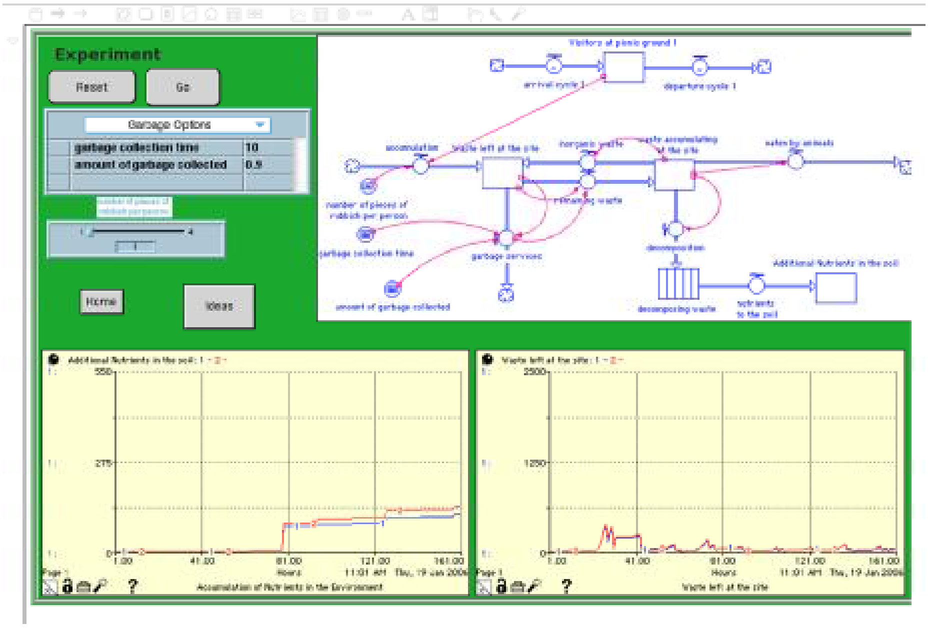

Figure 2: Experiment screen showing items that can be altered and graphs recording output

The dependent variable reported in this paper is knowledge of a socio-environmental system. The independent variable is the learning environment (individual or collaborative). Other independent variables including SES, attitudes towards both the environment and science, experience with computers, motivation/enjoyment of the learning experience, understanding of the system modelled and engagement with the materials were measured but not reported in this paper. Four instruments were developed to measure these variables. A *background questionnaire* identifies the gender, SES, computer skills, attitudes towards science and attitudes towards the environment of the students. In order to measure student's knowledge about the socio-environmental system an assessment task was developed. The assessment addresses general environmental knowledge and knowledge specific to the topic of National Parks management. Students were given this as a *pre-test* and a *post-test*. In this way, prior knowledge was controlled for, and we were able to determine what students learnt as a result of being exposed to the different materials. There was space on the pre-test to record post-test answers. When students completed the post-test, they either retained their pre-test response (by recording "as above" in the post-test space) or they recorded a different answer from that in the pre-test. Students were also encouraged to record the response "I don't know" if they did not know the answer to a question. A *final assessment* task was also developed in order to assess students' understanding of the model itself. Finally, an *evaluation* was used to determine students' motivation/enjoyment of the learning experience. In addition, screen captures of the students were recorded. These were processed into Quicktime movies, to determine the length of time students spent on task, running and manipulating the models, and the variables manipulated (Levy & Wilensky, 2005).

Altogether there were 15 students from two schools who participated in this part of the study. The first school, school 1, was an academically selective girls high school;

students who participated from this school were in year 10. The second school, school 2, was a girls 7-10 middle school; students who participated from this school were in year 9. There were six students in the collaborative learning experiment, all from school 1, nine students were involved in the individual learning experiment, four from school 1 and five from school 2. Students in both schools were given an introduction to the purpose of the experiment and a brief introduction outlining how the model would look, what could be changed for experiments, and expectations regarding their work.

Due to the scheduling requirements at each school, the progression through the experiment was different for each school. At school 1, students were introduced to the experiment and completed the background questionnaire, and one week later the first author returned to conduct the remainder of the experiment. At this point, students were given 20 minutes to complete the pre-test, 20 minutes to look at the materials, and 20 minutes to complete the post-test, ten minutes to complete the final assessment and five minutes to complete the evaluation. At school 2, students were introduced to the experiment and completed both the background questionnaire and the pre-test during the first meeting. The first author returned the followed day and students were given 20 minutes to examine the materials, and the remainder was as for school 1.

Results and Discussion

As was outlined above, two schools were used in the individual learning condition. The first step then was to determine whether the school had an effect on the results. A Mann Whitney test was used to compare the pre-test (school 1 Mdn=21; school 2 Mdn=11) and post-test (school 1 Mdn=17.5; school 2 Mdn=13.5) environmental knowledge scores for the individual learning (SI) group between the two schools. The results showed that there was no significant difference for either the pre-test environmental knowledge scores (U=3, p=.111, r=-.572) or the post-test (U=2, p=.063, r=-.653), although large effect sizes were present in both comparisons. For this reason it was decided that the results from school 1 and school 2 could be combined for use in the SI group.

The pre-test and post-test scores were then compared for the SI group using a Wilcoxon Signed Ranks test. In the SI group there was no significant difference between the pre-test (Mdn=11.5) and post-test (Mdn=15.5) environmental knowledge scores (T=28, p=.514, r=-.217). The same test was performed on the environmental knowledge scores from the collaborative learning (SC) group. There was a significant difference found between the pre-test (Mdn=18.75) and post-test (Mdn=23.5) environmental knowledge scores (T=15, p=.043, r=-.826).

The pre- and post-test environmental knowledge scores were then compared between the two groups using Mann-Whitney tests. There was found to be no significant difference between the pre-test environmental knowledge scores for the SI and SC groups (U=13.5, p=.114, r=-.414). There was, however, a significant difference between the post-test environmental knowledge scores for the SI and SC groups (U=4, p=.005, r=-.701). Figure 3 shows that the post-test environmental knowledge scores were higher in the SC group than in the SI group.

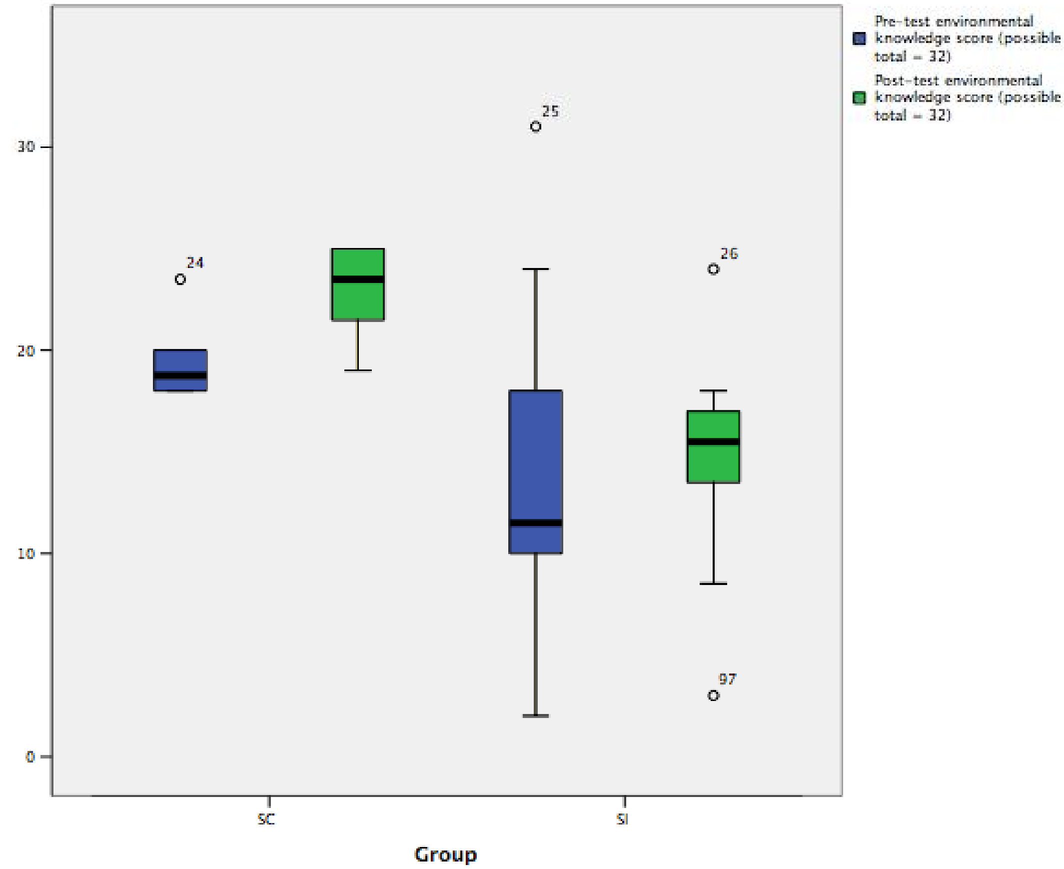

Figure 3: Box plot of the environmental knowledge pre- and post-test scores for the SC and SI groups

The similarity in the pre-test environmental knowledge scores in the SI and SC groups means that students in the two groups had similar levels of environmental knowledge before being exposed to the SDM. After the two groups were given the SDM, only those students in the collaborative learning condition increased their environmental knowledge, and in fact this environmental knowledge was not only significantly higher than their previous knowledge, but also significantly higher than that of those students in the individual learning condition. This indicates that if students are in a dyad they may be able to better understand the representation of a SDM than those who are approaching the model as an individual.

Further investigation of the remaining data collected as part of this study is required to explain these results. This will include analysis of students' understanding of the system itself (as opposed to the knowledge of environmental processes as explained above) as well as students' previous experience with computers and their enjoyment of the learning experience. It is expected that enjoyment of the learning experience will play a role because of the findings of the pilot study (Thompson & Reimann, 2006), which examined only those students in the individual learning condition. In the pilot study, it was found that students using the SDM did not find the content interesting, found the representation difficult to understand, did not want more time with the materials, and found it difficult to visualise the real situation. They interacted less with the model than students with other representations. This may go some way to explaining the above results.

Although still a preliminary finding, the results reported in this paper, that students who interrogated a SDM in a collaborative learning environment significantly increased their environmental knowledge, while those in an individual learning environment did not, has interesting implications for the use of SDM in educational settings. It may be that school students need this collaborative learning environment when learning from SDMs in order to understand this abstract, yet powerful representation.

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