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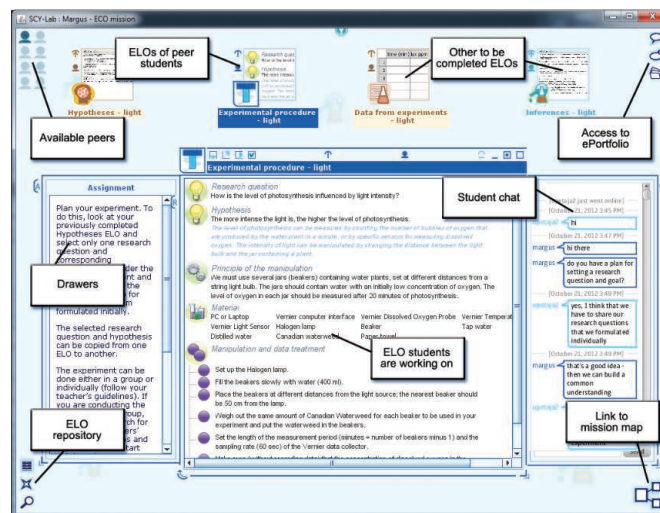
Investigating Ecosystems as a Blended Learning Experience

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Learning by inquiry, collaboration, and design are the central didactic principles of the software developed by the Science Created by You (SCY) project. In SCY technology-enhanced learning environments, or SCY missions, students learn by creating products that they can share and discuss with their peers. In order to do this, they make use of textual or multimedia learning materials and perform physical and virtual experiments.

Each SCY mission has a specific research or design goal, for example, to create a healthy pizza or a house where the CO₂ balance is close to zero. Along their way to this final product, students create many types of intermediate virtual products or Emerging Learning Objects (ELOs). ELOs can include concept maps, experimental procedures, models, and data sets from simulations or from real experiments. All activities in SCY missions, center around ELOs, which students can save, retrieve, and edit.

Four SCY missions have been developed around topics such as the greenhouse effect, food and nutritional values, and DNA [see (1) and www.scy-net.eu/]. Here, we focus on what we have called the ECO mission. This mission, for secondary school, ages 15 to 19, primarily addresses the area of ecology and includes chemistry and math subject matter. The ECO mission combines hands-on data collection with working in the SCY software environment. It starts by asking students to create a concept map of the different relations in a freshwater body that will present their initial knowledge about the domain. This can be done individually or collaboratively with student peers. Next, students follow four pre-defined different inquiry cycles on related



Example of a SCY mission interface (from the ECO mission). In the inquiry cycle on light, students collect data on light intensity, water temperature, and dissolved oxygen level. Canadian waterweed is placed in beakers of tap water. Light intensity is changed by moving the beakers different distances from a halogen lamp. Data are collected with mobile Vernier devices, and digital data can be imported into the SCY environment. Students can visualize the changing concentration of oxygen in the beakers and collect real data from which to infer the relation between light intensity and photosynthesis. These data also often prompt discussions on validity and limitations of scientific research.

topics: (i) the role of light in the level of photosynthesis, (ii) the concept of pH and pH changes in a water body, (iii) the influence of nutrient concentration on primary production, and (iv) relations between trophic levels in an ecosystem. These topics were selected on the basis of analysis of the curricula in Estonia, Cyprus, France, Norway, and the Netherlands and fine-tuned by means of expert interviews. After having gone through the four inquiry cycles, students return to their initial concept map to adapt it on the basis of the knowledge gathered in their inquiry.

In the interface that is shown in the screen shot above[ck], students design an experimental procedure during the inquiry cycle, for a hands-on experiment on the role of light in photosynthesis. The experimental procedure under development is open in the center of the screen. A guiding assignment and information sources for creating the ELO are located in “drawers,” or extendable windows attached to the ELO. Chat communication is available in a drawer, and peers are invited by dragging their avatar (top left corner) to the ELO. Navigation takes place through the mission map (bottom right corner), and the bottom left corner houses the ELO repository where students can save, search, and retrieve their own and their peers’ ELOs. More information on the SCY didactic principles and learning environment can be found in (1, 2).

In another physical experiment from the inquiry cycle on pH changes, students put sand, limestone fragments, and granite fragments in different beakers to discover the effect that the composition of a lake bottom could have on pH rise in the lake from acid precipitation. Distilled water is poured into the beakers, followed by different concentrations of sulfuric acid. The pH in all beakers is measured, and data analysis in the SCY environment enables students to understand why similar acid rain could have different effects on the life in various freshwater lakes.

In the inquiry cycle on nutrient concentration, students alter the concentration of nitrogen and phosphorus in water and observe the effect on algae biomass fluctuations. The simulation model takes into account the chemical affinity of nitrogen and phosphorus in forming compounds and the population growth and mortality characteristics. Here, students are provided with data that could otherwise only be collected in a lengthy real-life experiment.

In a simulation on trophic levels, values characterizing predator and prey in an ecosystem can be used as either input or output variables. Population gains and losses, ability to catch and feed on prey, natural growth and death factors, and the ability to convert prey biomass to predator biomass are specific elements in this simulation. Students can alter

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the initial level of biomass of the components and then investigate changes for a specified time period.

The investigations done in each inquiry cycle (see the photos), together with scientific background information, are necessary for solving the problems introduced in each cycle's initial design or research goal. In addition, these outcomes should help students to redesign the concept map that they had created at the start. Students also develop a video report to illustrate their inquiry processes.

The ECO mission has been implemented in several schools in Estonia, the Netherlands, and Cyprus. Assessment in Estonia involved 64 students (ages 16 to 18) from secondary schools. In each trial site, students worked individually with the ECO mission for 4 hours. At the beginning of the session, an online pretest was completed. A posttest was completed online 2 weeks after the intervention.

Students' initial and final revised concept maps were analyzed in order to assess their conceptual knowledge. The results indicated a significant improvement in students' conceptual knowledge (Wilcoxon signed-rank test: $Z = -5.92$; $P < 0.001$). After working with the ECO mission, students were better able to organize and represent their knowledge about relations between biotic and abiotic factors in freshwater ecosystems.



Learning in a SCY mission. (A) A student planning an experiment. (B) Students measuring light intensity and dissolved oxygen level in water. (C) Waterweed in a beaker. (D) Vernier device for measuring dissolved oxygen level.

Pre- and posttests assessed changes in students' inquiry skills. In both tests, an everyday problem situation related to ecology was presented. Students were then asked to formulate research questions and hypotheses. Next, a graph with experimental data was presented, and students answered questions

about the graph in order to demonstrate their data analysis skills. The final task was to make inferences on the basis of the results of an experiment. Research questions were scored for three elements—the maximum score was given if a question related to the problem was formulated and if it included the correct dependent and independent factors. Hypotheses and inferences were scored on the basis of formulation (a sentence related to the research question), correct dependent and independent factors, and relation with background information. The comparison of pre- and posttests detected a statistically significant improvement in students' skills formulating research questions (Wilcoxon signed-rank test:

$Z = -3.67$; $P < 0.001$) and hypotheses ($Z = -2.78$; $P < 0.05$). As students' skills analyzing data and making inferences were already high before the intervention, significant improvement was not seen. The results indicated that after working on the ECO mission, students were better able to relate research questions and hypotheses and to correctly identify dependent and independent factors from background information. According to the teachers' feedback, the ECO mission enriches the school curriculum with innovative blended learning opportunities that combine learning in the classroom and the computer lab with authentic data collection.

Supplementary Materials

www.sciencemag.org/cgi/content/full/340/6140/1537/DC1

References and Notes

1. T. de Jong *et al.*, *Educ. Technol. Res. Dev.* **60**, 883 (2012).
2. T. de Jong *et al.*, *Br. J. Educ. Technol.* **41**, 909 (2010).

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