Shroomroot: an action-based digital game to enhance postsecondary learning about mycorrhiza

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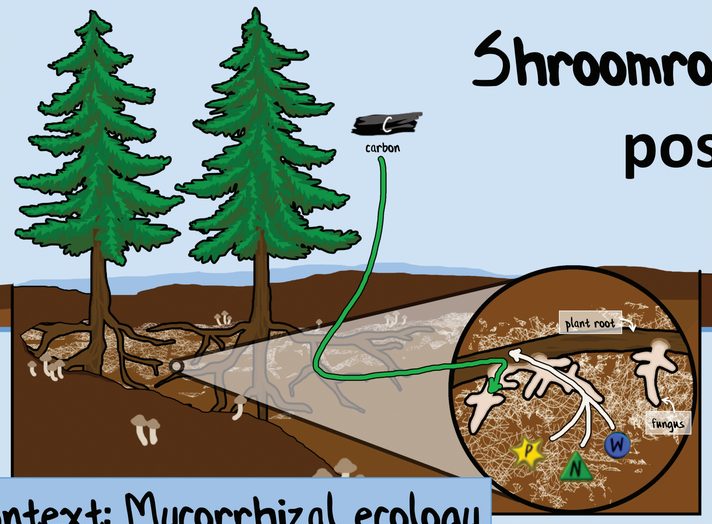

Context: Mycorrhizal ecology

Mycorrhizae are symbiotic relationships in which fungi provide their plant host with soil-based resources such as N, P, and water (W), and the plant provides the fungus with products of photosynthesis that contain C. When multiple plants are connected by the same fungus, resource exchange can occur across mycorrhizal networks, which are important in ecosystems worldwide – affecting nutrient cycling, soil aggregation, forest stand dynamics, and many other ecosystem processes.

Mycorrhizal root tips

Bird's eye view of forest
Using some artistic license to peer through the soil to see the mycorrhizal network

Central Question

Mycorrhizal ecology is complex, occurs belowground, and is close to impossible to observe in action. This makes it a challenging subject to learn, especially in introductory university forestry and soil science courses, in which the topic of basic mycorrhizal ecology is often covered.

Is a video game an effective and engaging way to teach undergraduates about soil ecology, particularly mycorrhizae?

Digital games can offer unique learning opportunities that allow immersion and direction interaction with systems of interest. Games focused on both animal and plant ecology have increased student learning and engagement in other studies. To our knowledge, however, there are no studied examples of belowground-oriented games in which the player assumes a role of a plant and controls its growth in a physically tangible way.

We created and evaluated the game Shroomroot, in which players direct growth of a Douglas-fir root, collecting nutrients and interacting with mycorrhizal fungi.

Acknowledgements

Thank you to the students and instructors in the 2014-2015 Introduction to Soil Science course for their participation, Rik Blok for advice along the way, and UBC TerreWEB for contributing to the development of Shroomroot with funding and encouragement.

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Shroomroot the game

Objective #1 was to build Shroomroot, an action-based, plant-centric game, situated in the world of belowground ecology and aimed for an introductory soil science course.

As the player progresses through the 12 levels of the game, their plant root drains its resources, and the player has to acquire new resources quickly to prevent starvation. Halfway through the game, the root can interact with fungi and form mycorrhizal associations and mycorrhizal networks, thereby expanding the resource-gathering dynamic to include organic nutrients and a wider collection radius.

Level 1

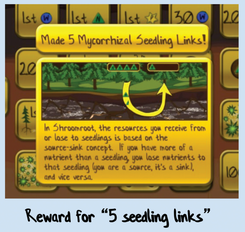
Level 3

Level 8

Level 12

Players can also unlock "Rewards" for achievements such as the number and type of resources collected, or the number and types of mycorrhizal relationships. For example, the "Made 5 Mycorrhizal Seedling links" reward, once unlocked, shows a picture and description of the source-sink pattern of resource transfer through mycorrhizal networks (below).

Rewards screen



Reward for "5 seedling links"

Game-building and availability

Shroomroot was designed and developed by J. Amerongen Maddison and C. Adderley, based on personal experience playing and building digital games, pedagogical theory, and consultations. Shroomroot was developed using the Unity 3D game engine and can be played via Firefox or Safari with the free download of the Unity web plugin.

Shroomroot is available for free at http://shroomroot.com/game.html.

Evaluating Shroomroot

Objective #2 was to perform an exploratory evaluation of Shroomroot as an educational tool using a quantitative pre-test/post-test design.

We evaluated Shroomroot (SR) in an Introduction to Soil Science at University of British Columbia during the 2014-2015 academic year. After matching pre- and post-tests via anonymous usernames, 52 students participated in the assessments and gameplay, as described below.

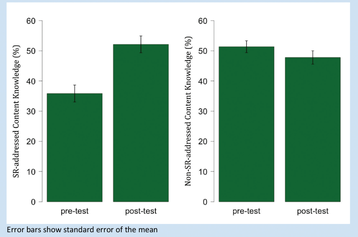
Assessments

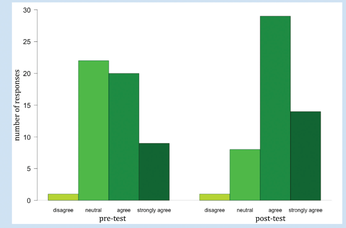
- Pre- and Post-test with identical knowledge and engagement questions
- Multiple choice questions tested students' knowledge of mycorrhizae, divided into content addressed by SR and content not addressed by SR
- Likert items tested student engagement with mycorrhizal content
- Optional and anonymous, delivered online and on paper

Intervention

- Participating students took the pre-test within 2 days before game-play
- Played Shroomroot during one 50 min lecture session
- Played in groups of 2-3 on laptops or phones for about 35 min of game time
- Took post-test within 2 days after game-play

Results and Discussion





Error bars show standard error of the mean

- Students' SR-addressed mycorrhizal knowledge significantly increased (from a 36% average on the pre-test to a 52% average on the post-test)
- Likert results trended towards increased student engagement (content engagement item "Mycorrhizae and mycorrhizal networks are interesting" saw 56% of students reporting Agree or Strongly Agree on the pre-test vs 83% reporting Agree or Strongly Agree on the post-test)
- Students self-reported that the game increased their learning (78% Agreed or Strongly Agreed) and interest in mycorrhizae and mycorrhizal networks (also 78% Agreed or Strongly Agreed).

Take Home Messages

1. Shroomroot increased knowledge and tended to increase engagement, suggesting it may be a positive educational tool for appropriate courses (introduction to soil science, forest ecology).
2. Informal instructor feedback and researcher observations suggest that learning from Shroomroot may be improved if paired with guided questions or other forms of instructor support.
3. This study emphasizes the importance of the creative collaboration between game developers and science instructors in developing educational digital gaming content, especially for challenging and complex worlds like belowground ecosystems.