feature article

engaging students in global engineering problems:

flooded rice fields during water shortages

Connecting students with these types of real-world issues—that affect and impact many individuals on a daily basis—can be motivating, educational, and engaging.

by
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Introduction

Engaging students in complex real-world challenges—each with a plethora of side effects, connected pieces, and stakeholders—can spur a lasting connection that can encourage future aspirations and success. Educators can use hands-on engineering design-based assignments as one approach to engaging students in these real-world problems that form connections to people and places around the world (Grubbs & Strimel, 2015). In addition to the connections made through these activities, studies have shown that these real-world engineering design activities encourage teamwork, the development of other 21st century skills (Partnership, 2017), and a sustained passion for engineering (Knight, Carlson, & Sullivan, 2007; Quinn & Albano, 2008). Further, empathy from user-centered design may be cultivated in students as they work to understand, study, and assist the people affected by these situations.

Above: Figure 4. Flooded rice fields in the Philippines (Bartholomew, 2016).

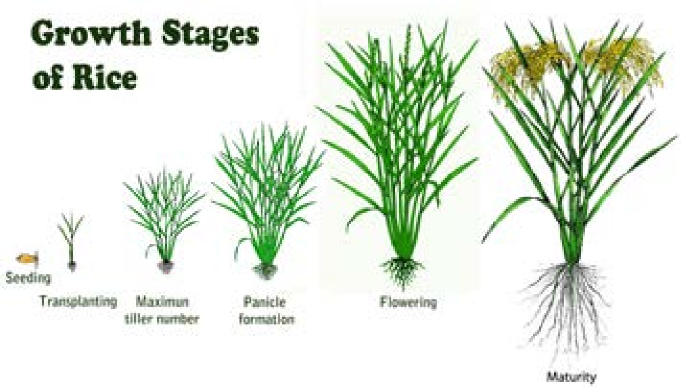

Figure 1. Rice plant growth stages. Image obtained from: www.flickr.com/photos/ricephotos/13597007274.

Figure 2. Harvested Rice in the Drying Stage in the Philippines (Bartholomew, 2016).

Growing and Harvesting Rice

Rice, a type of grass similar to wheat and corn, is rich in nutrients, vitamins, and minerals and is the primary food source for more than three billion people worldwide (Ricepedia, 2017). Rice requires massive amounts of water to grow and is grown in large fields that are prepared using various methods, tools, and approaches. All rice plants go through four main stages of growth: germination, vegetative, reproductive, and ripening (Figure 1).

Farmers plow the fields to allow the seeds to be planted at the right depth and also help with weed control. Plowing is followed by leveling, which is done to ensure equal water depth for optimal rice growing (Pinoy Rice Knowledge Bank, 2010). Rice seedlings are started in beds and, after a period of 30-50 days, are transplanted to the fields. Once planted, the rice fields are flooded periodically while the rice grows.

Initially, the rice seed is dormant until it absorbs water and is exposed to a temperature between 50°F and 104°F. Rice germination begins as the first roots' shoots sprout up from the seed and the plant starts to grow. The vegetative phase of rice cultivation is characterized by the development of tillers and leaves and a gradual increase in height. This phase is followed by the reproductive, or heading phase, which starts as the leaf stem begins to bulge with a rice panicle enclosed. Lastly comes the ripening phase, which simultaneously starts during flowering as the reproductive phase is ending. As the rice goes through this final stage, it goes from being milky, doughy, and yellow, to ripe, white, and then mature (GRiSP, 2013). When the field is ready for harvest, the fields are drained and the stalks are cut and dried (Ricepedia, 2017). Once completely dry, the rice stalks are threshed—a process that involves shaking or beating the stalks to remove the rice kernel—and then the rice kernels are shelled.

Rice Production and World Water Shortages

A water shortage, especially in a heavy rice-producing area, causes food production to slow and food insecurity to become more prevalent (Hanjra & Qureshi, 2010). Due to rapid urbanization worldwide and unsustainable economic practices, the quantity and quality of water is dropping (Eliasson, 2015). For example, in 2015, roughly 800 million of the 7.1 billion people in the world did not have access to safe and secure water resources (Pink, 2016). This is further impacted by climate change, which can seriously disrupt food and water supplies in all areas by "altering the spatial and temporal distribution of rainfall, the availability of water, and other agricultural production factors" (Kang, Hao, Du, Tong, Su, Lu ... & Ding, 2016). Rice-producing areas such as China, Indonesia, the Philippines, and California have all recently experienced droughts (NIDIS, 2017), suggesting that proactive water management practices may be necessary to ensure that rice crops have enough water for their growing period (Ricepedia, 2017).

Figure 3. Stream feeding rice paddies (Bartholomew, 2016).

While some promising efforts have recently been made to connect farmers with new practices of water conservation and assist in the optimization and use of resources (Cantwell, 2016; Kalcic, 2013), these efforts have not eliminated the need for additional research and sustainable practices in farming. This is especially true for crops such as rice that rely heavily on large quantities of water for each stage of cultivation and maturation. Specifically, it is estimated that rice accounts for 64-83% of irrigated area in Southeast Asia and 46-52% of irrigated area in East Asia (Dawe, 2005), and other research has identified that 90% of global rice is produced in fields with standing water (Dawe, 2005). While some efforts are underway to adapt current rice varieties for drier conditions (Bindraban, Hengsdijk, Cae, Shi, Thiyagarajan, Krogt, & Wardana, 2006), the need to account for prevention of weeds, pests, and illness (GRiSP, 2013) has resulted in most farmers still utilizing traditional growing methods (Bindraban, et al., 2006). By 2025, estimates show that 15-20 million hectares (1 hectare = 2.47 acres) of irrigated rice will suffer some degree of water scarcity (GRiSP, 2013).

Conclusion

Technology and design efforts are underway to increase water input productivity by decreasing losses from seepage and other issues. Processes for better management (GRiSP, 2013) and other incentives have been used to increase water conservation (Dawe, 2005), but these efforts are largely exploratory and common farmers still need the tools to fully implement water conservation in their personal fields. Applying engineering design to ensure adequate global access to water for agricultural and other needs is currently one of the National Academy of Engineering's Grand Challenges (National Academy of Engineering, 2017) and, as students engage in this Grand Challenge through the accompanying lesson plan, they will work in teams to contribute to an area of great need worldwide. Throughout the lesson plan (posted on the ITEEA website at ???), students will develop and grow the skills aligned with *Standards for Technological Literacy*—specifically Standard 15 (Agriculture and Related Biotechnologies)—as they focus on the materials available to rice farmers and how they can utilize those materials to protect and aid their crops.

This lesson could frame a semester course focused on examining global engineering issues, be included as part of a larger materials-engineering unit (as this lesson focuses on materials testing), or open into a more student-guided unit that investigates other ways to tackle water shortages. We suggest that teachers implementing this lesson provide at least four natural materials with different properties to allow for student growth and experimentation and caution that students who are not familiar with the scientific method or design process may need additional review or instruction on these two topics.

As water shortages—caused by droughts, lack of retention infrastructure, or other issues—can severely impact staple crops like rice and be especially devastating for farmers and businesses in developing countries, this issue is one of significant importance. Connecting students with these types of real-world issues—that affect and impact many individuals on a daily basis—can be motivating, educational, and engaging. Teachers are encouraged to use and modify the topics, plans, and materials (posted on the ITEEA website at www.iteea.org/TETMar19Haney.aspx) to fit specific needs in terms of students, course objectives, and unique circumstances.

References

Bartholomew, Scott R. (2016). Trip to the Philippines [Photographs].

Bindraban, P. S., Hengsdijk, H., Cao, W., Shi, Q., Thiyagarajan, T. M., Krogt, W. V., & Wardana, I. P. (2006). Transforming inundated rice cultivation. *International Journal of Water Resources Development, 22*(1), 87-100. doi:10.1080/07900620500405338.

Cantwell, M. (2016). *A national policy framework to address drought and water security in the United States.* Retrieved from www.energy.senate.gov/public/index.cfm/files/serve?File_id=03D88F56-1AE2-4DEE-A3EC-7CAC0E9BCF03

Dawe, D. (2005). Increasing water productivity in rice-based systems in Asia – Past trends, current problems, and future prospects. *Plant Production Science, 8*(3), 221-230. doi:10.1626/pps.8.221

Eliasson, J. (2015). The rising pressure of global water shortages. *Nature, 517*(7532), 6-7.

Global Rice Science Partnership (GRiSP). (2013). *Rice almanac: Source book for one of the most economic activities on Earth* (4th ed.). Los Baños, Philippines: International Rice Research Institute.

Grubbs, M. & Strimel, G. (2015). Engineering design: The great integrator. *Journal of STEM Teacher Education, 50*(1), 8.

Hanjra, M. A. & Qureshi, M. E. (2010). Global water crisis and future food security in an era of climate change. *Food Policy, 35*(5), 365-377.

Ivey, J. L., Smithers, J., de Loë, R. C., & Kreutzwiser, R. D. (2004). Community capacity for adaptation to climate-induced water shortages: Linking institutional complexity and local actors. *Environmental Management, 33*(1), 36-47.

Kalcic, M. M. (2013). *Adaptive targeting: Engaging farmers to assess perceptions and improve watershed modeling, spatial optimization, and adoption of agricultural conservation practices* (Order No. 3613158). Available from Dissertations & Theses @ CIC Institutions; ProQuest Dissertations & Theses Global. (1511021944). Retrieved from https://search-proquest-com.ezproxy.lib.purdue.edu/docview/1511021944?accountid=13360

Kang, S., Hao, X., Du, T., Tong, L., Su, X., Lu, H., ... & Ding, R. (2017). Improving agricultural water productivity to ensure food security in China under changing environment: From research to practice. *Agricultural Water Management*, 179, 5-17.

Knight, D. W., Carlson, L. E., & Sullivan, J. F. (2007, June). Improving engineering student retention through hands-on, team-based, first-year design projects. In *Proceedings of the International Conference on Research in Engineering Education*. Honolulu, HI.

National Academy of Engineering. (2017). *Provide access to clean water.* Retrieved from www.engineeringchallenges.org/9142.aspx

NIDIS. (2017). *Global drought information system.* Retrieved from www.drought.gov/gdm/content/welcome

Partnership for 21st Century Skills (P21). (2017). *Framework for 21st century learning.* Retrieved from www. p21.org/our-work/p21-framework

Pink, R. M. (2016). Introduction. In *Water rights in Southeast Asia and India* (pp. 1-14). Palgrave Macmillan U.S.

Pinoy Rice Knowledge Bank. (2010). *How to prepare the rice field.* Retrieved from www.pinoyrice.com/wp-content/uploads/how-to-prepare-the-rice-field.pdf

Quinn, K. A. & Albano, L. D. (2008). Problem-based learning in structural engineering education. *Journal of Professional Issues in Engineering Education & Practice, 134*(4), 329-334. doi:10.1061/(ASCE)1052-3928(2008)134:4(329)

Ricepedia. (2017). Retrieved from http://ricepedia.org/

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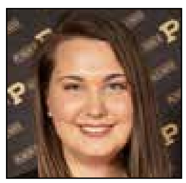

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NOTE: The following additional resources associated with this article are also posted on the ITEEA website at: www.iteea.org/TETMar19Haney.aspx

Table 1 – Lesson Overview

Table 2 – Lesson Plan

Appendix A: Materials Testing

Appendix B: Rice Field Research

Appendix C: Materials and Agricultural Engineering: Rice Fields Rubric

Appendix D: Sample Design Portfolio Presentation