Enhancing Student Interest in the Agricultural Sciences through Aquaponics

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ABSTRACT

Educators in grades K–16 have recently placed renewed interest in experiential learning activities for teaching science and mathematics. Agriculture offers numerous authentic activities that can serve as meaningful contexts for teaching and learning. The AgriScience Education Project at the University of Arkansas was established to develop and disseminate agriculturally related teaching and learning materials and activities that teachers can use to teach science and mathematics. The objective of this paper is to describe the Aquaponics in the Classroom program, one of the most successful components of the AgriScience Education Project. Teachers participating in this program receive a classroom-scale aquaponics unit, a packet of printed instructional materials, and a set of student laboratory activities that use aquaponics as a context for teaching and learning science and mathematics. The project has helped teachers of kindergarten through high school classes create aquaponics programs. Primary interest has been from teachers at the middle-school and junior high school grade levels.

In recent years, many curriculum development projects have promoted experiential learning as both an effective and enjoyable way for students to master science and mathematics content (Hodson, 1990). According to Borko and Putnam (undated, p. 35), educators are showing "renewed interest in how learning in schools might be better contextualized or situated in meaningful settings so that the resultant knowledge is…more accessible and useful to students…"

Agriculture offers numerous authentic activities that can serve as meaningful contexts for teaching and learning (National Research Council, 1988). One of the primary purposes of the AgriScience Education Project at the University of Arkansas is to develop and disseminate agriculturally related materials and activities that elementary, middle, and secondary teachers can use to teach academic content, especially in science and mathematics (Wardlow, 1996). A major objective of the AgriScience Education Project is to increase student achievement and motivation and to enhance both students' and teachers' interest in agricultural sciences and technologies.

The Aquaponics in the Classroom program is one of the most successful components of the AgriScience Education Project. Teachers participating in this program receive a classroom-scale aquaponics unit, a packet of printed instructional materials, and a set of student laboratory activities that use aquaponics as a context for teaching and learning science and mathematics.

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PURPOSE AND OBJECTIVES

The purpose of this paper is to describe the Aquaponics in the Classroom project. Specific objectives are to:

1. Describe the need for and the development of the project
2. Describe the classroom-scale aquaponics unit and instructional materials provided to teachers participating in the project
3. Describe teachers' perceptions of the aquaponics unit, instructional materials, and support provided

Project Description

Aquaponics, the integrated culture of aquatic animals and plants grown in a soil-less environment, provides an excellent context for the teaching, learning, and application of academic content, particularly in science and mathematics. Aquaponics also serves as an effective context for integrating the agricultural sciences and technologies into *academic* courses. Thus, the AgriScience Education Project at the University of Arkansas has made the infusion of aquaponics into the school curriculum one of its primary goals.

A prototype classroom-scale aquaponics unit was constructed, pilot-tested in two classrooms, and used in science and mathematics teacher workshops that the authors conducted during 1997 and 1998. Participating teachers expressed a great deal of interest in the aquaponics unit and associated instructional materials. However, this interest was somewhat tempered by the cost of commercially available units (minimum of $1500–$2000). The prototype unit was much less expensive (approximately $350 in materials). However, some teachers felt they lacked the money, time, equipment, and/or expertise necessary to build the unit.

To overcome this limitation, 16 aquaponics units were constructed and made available to teachers on a no-cost, loan basis. The normal loan period is one semester, but several teachers have requested extensions and used the units for an entire academic year. Over the past 3 yr, the 16 units have been placed in 38 classrooms. The demand for the units has exceeded supply and a number of teachers are on a waiting list to receive units. Current plans call for the construction of six more units to be placed in the 2002–2003 school year. The project-owned aquaponics units have been placed in schools in Arkansas, Kansas, Oklahoma, and Missouri. Teachers from across the country have requested information and assistance in constructing their own units, based on these plans.

Abbreviations: GFCI, ground-fault circuit interrupter.

Aquaponics Unit and Instructional Materials

In developing the classroom-scale aquaponics unit, five criteria were deemed essential: safety, compactness, quiet operation, portability, and low-cost. The primary safety concern was the use of electricity (for motor and lights) in a wet environment. To enhance electrical safety, a portable ground-fault circuit interrupter (GFCI) was provided along with each unit. A compact design was necessary because most of the units were placed in regular classrooms. As designed, the unit only required 1.39 m^2 (15.0 ft^2) of floor space. Quiet operation, essential so that noise from the unit would not interfere with normal teaching and learning activities, was enhanced by returning water to the main tank below water level. Portability was enhanced through light-weight, modular construction, which allows the unit be easily assembled, disassembled, and transported. Finally, low cost (approximately $350) was achieved through the use of commonly available, inexpensive construction materials.

The primary components of the aquaponics unit (see Fig. 1) are the fish culture tank, biofilter/aerator, plant growth

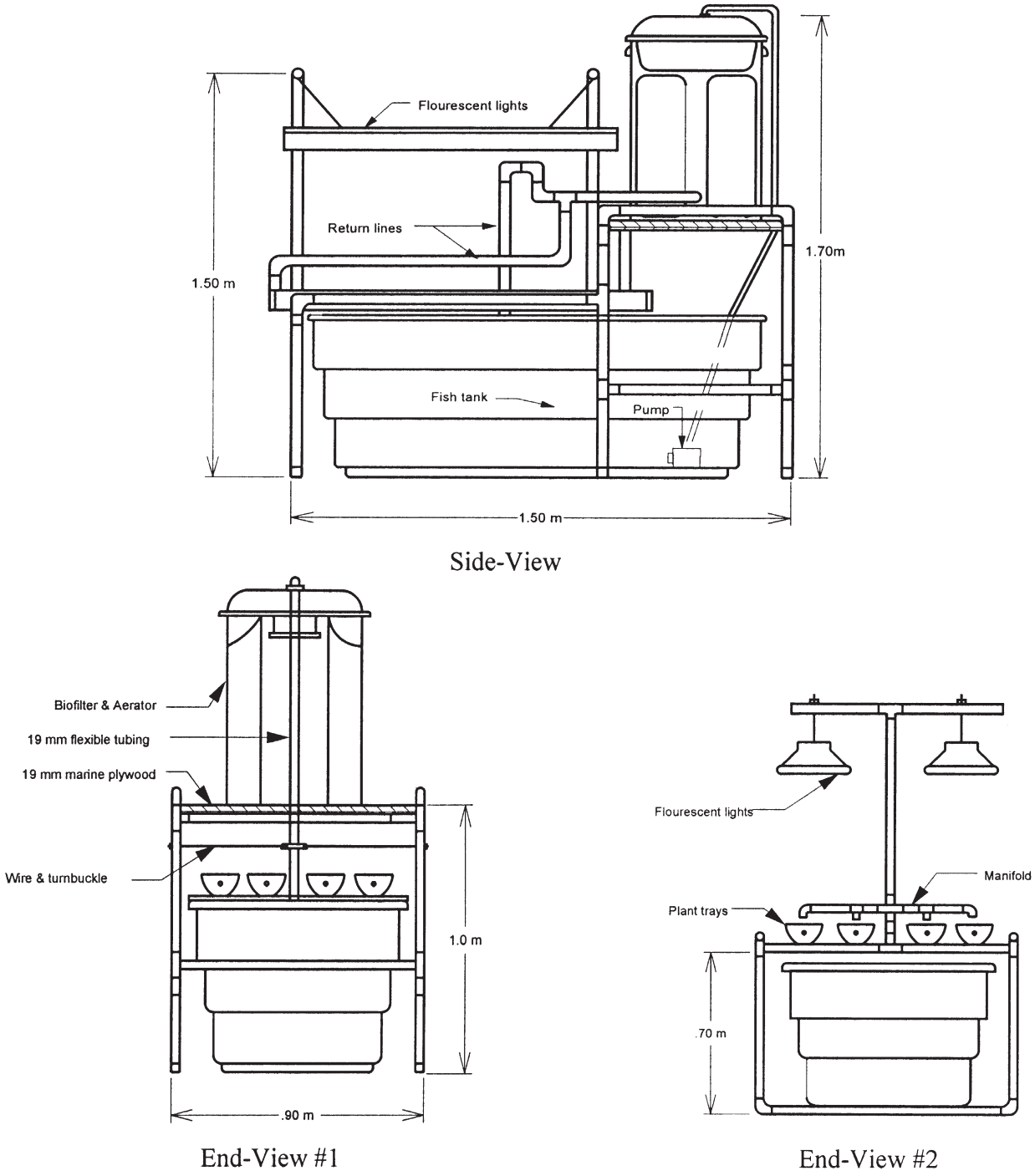

Fig. 1. Classroom scale aquaponics unit. Note: All structural components are 2.5-cm (1-inch) PVC pipe, unless otherwise noted.

trays, pump and hoses, and support assembly. The fish culture tank is a 378-L (100-gallon) formed rubber livestock water tank; the interior was painted swimming pool blue to increase visibility.

The biofilter–aerator is of the packed tower design (Losordo et al., 1992) and consists of a 76-L (20-gallon) plastic garbage can nested inside a 114-L (30-gallon) plastic garbage can. The small can, filled with nonsoluble packing media, has holes drilled in the side and bottom to allow air and water to flow. Water from the fish tank is pumped to the top of the biofilter–aerator and is dispersed across the packing media through a perforated plastic tray. Water flows through the packing media under nonflood conditions and exits into the large can. An outlet from the large can allows the water to gravity-flow to plastic hoses going to the hydroponic plant growth trays or directly back to the fish tank.

The plant growth trays are 1.2-m (4-foot) lengths of vinyl house guttering with end caps. Plants are supported in the trays using strips of foam board. A 0.15-kW (0.2-hp) submersible electric pump is used to lift the water from the fish tank to the biofilter–aerator through 1.9-cm (0.75-inch) flexible plastic tubing. All of the primary structural framework is made from 2.5-cm (1-inch) PVC pipe.

A printed set of instructional materials has been developed and is provided to each teacher receiving an aquaponics unit. The materials include introductory information on aquaponics and the aquaponics unit, as well as a series of student laboratory activities (Fig. 2). Example activities include, "Determining Water Cycle Rate" and "Determining Feed Conversion Rate" (mathematics); "Monitoring NH_3, Dissolved O_2, and pH Levels" and "The Nitrogen Cycle" (chemistry); "Evaluating Pumping Efficiency and Power Factor" (physics); and "Plant Structures and Functions" (biology). These materials emphasize the application of mathematics and science to optimize an engineered agricultural production system. Thus, the agricultural sciences and engineering are an integral component of the instructional materials.

Fig. 2. Elementary school students examine root growth in the soil-less environment of an integrated aquaculture–hydroponics unit. (Photo courtesy of G. Wardlow and D.M. Johnson, University of Arkansas.)

The development of a single set of instructional materials that would be applicable to every course would be impossible. Therefore, in addition to the materials provided, project staff members consult with participating teachers individually to help develop activities that integrate the aquaponics unit into the established curriculum. These teacher contacts provide an excellent source of ideas for the development of additional materials.

Teacher Perceptions

Informal feedback from teachers and students, as well as the numerous requests for additional units, has indicated a high level of satisfaction with the classroom-scale aquaponics units. To assess teacher perceptions of the Aquaponics in the Classroom program, surveys were sent to 10 teachers using loaner aquaponics units during Spring 1999. The results are presented in Table 1.

As shown in Table 1, the teachers were extremely positive in their perceptions of various aspects of the Aquaponics in the Classroom project. All of the teachers strongly agreed that their students were "interested in the aquaponics unit" and that they "would like to keep the aquaponics unit" for another year. The teachers also strongly agreed that they would recommend the aquaponics unit to colleagues. They were satisfied with the level of support provided by the AgriScience Project staff, and that their students had asked questions about science as a result of interacting with the aquaponics unit. The teachers were in moderately strong agreement that having the aquaponics unit in their classroom provided students with opportunities for research and to share their experiences raising plants and fish.

The teachers agreed that "the aquaponics unit is used in my classroom curriculum." However, they were less likely to agree that they either used the activities provided by the AgriScience Education Project staff or they developed their own classroom activities involving the use of the aquaponics unit in the classroom.

Table 1. Teacher perceptions of the classroom-scale aquaponics unit and materials (n = 10).

Survey statement	Mean†
My students are interested in the aquaponics unit.	5.0
I would like to keep the aquaponics unit in my room again next year.	5.0
I am happy to have an aquaponics unit in my classroom.	4.8
I would recommend the aquaponics unit to other teachers.	4.8
I am satisfied with the support provided by the AgriScience staff.	4.8
Students have asked science-related questions because of their interaction with the aquaponics unit.	4.8
Visitors to my classroom, other teachers, or administrators have shown an interest in the aquaponics unit.	4.8
My students check on the plants and fish on a regular basis.	4.5
Having the aquaponics unit in my classroom has created an opportunity for student research.	4.5
Students have shared experiences about raising fish or growing plants while talking about the aquaponics unit.	4.5
The aquaponics unit is used in my classroom curriculum.	4.2
Students have asked questions about fish farming or hydroponics because of their interaction with the aquaponics unit.	4.0
The booklet *Aquaponics in your Classroom* has provided most of the information I needed to use the unit.	4.0
My students have taken pride in the care of the aquaponics unit.	3.8
I have used one (or more) of the activities provided by the AgriScience staff.	3.5
At least one classroom activity that I developed involved the use of the aquaponics unit.	3.2

† Based on a scale where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree.

SUMMARY AND CONCLUSIONS

To integrate the study of science and mathematics with the agricultural sciences and technologies, a classroom-scale aquaponics unit was developed for use in elementary, middle, and secondary classrooms and a set of instructional materials was developed. Loaner units have been placed in 27 schools in four states. Participating teachers have been very positive about the Aquaponics in the Classroom project. However, more information is needed concerning how teachers and students actually use these units and instructional materials to meet the objectives of their curricula. Interested educators are encouraged to contact the authors for more information.

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