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Perceived Usefulness of Aquaponics to Teach Agriculture, STEM, and Life Skills in the Classroom

Abstract

We surveyed 117 teachers to investigate perceptions of classroom-based aquaponics as a teaching tool for STEM, life skills and student engagement. Overall, respondents perceived Aquaponics as useful. Agriculture teachers perceived higher utility for teaching agriculture, lower student engagement, and lower utility for collaborative learning compared to non-agriculture teachers. Science teachers perceived lower utility of aquaponics as a teaching tool for agriculture, math, and physics compared to non-science teachers. We found a time in teaching effect for life skills but no time effect for usefulness as a teaching tool. We attribute this to sample size and recommend efforts to link aquaponics and academic subjects.

Introduction

Aquaculture is the fastest growing segment of agriculture expanding at a rate of 7-10% globally for the last 30 years (Boyd and McNevin, 2015). Teachers have been using aquaculture as a platform to teach agriculture and a variety of science, technology, engineering, and math (STEM) topics since the late 1980s (Cline, 2011; Wingenbach, 1998). According to Mengel (1999) aquaculture "… makes learning practical, experiential, and enjoyable for teachers and students." In 1998, the National Council for Agriculture Education developed a comprehensive Aquaculture curriculum for use in secondary classrooms around the country. The curriculum provided a basic training platform, and the idea flourished that aquaculture, and more recently, aquaponics may be an excellent tool for teaching a variety of academic subjects.

Aquaponics is a multifaceted agricultural practice that combines science from aquaculture and hydroponics. In aquaponics, fish consume feed and produce waste products that serve as fertilizer for plants. This creates two marketable products from one nutrient source. In a classroom setting, aquaponics exposes students to a variety of biology, chemistry, ecology, math, physics, business, and food safety principles (Genello et al., 2015; Mullen, 2003). Small-scale aquaponics systems can be made from recycled materials and are excellent tools for teaching natural science concepts at all levels and can mimic larger scale systems while minimizing environmental impacts (Maucieri et al., 2018). The purpose of this study was to evaluate if aquaponics is perceived as a useful tool for 1) teaching a variety of subjects, 2) teaching several life skills, and 3) engaging students.

Materials and Methods

This study utilized data from an online survey designed to capture current perceptions and practices of aquaponics stakeholders (Pattillo, 2021). The survey was developed by investigators incorporating principles from Dillman (2007) and themes from a 2013 aquaponics industry survey (Love et al., 2014). Content and face validity were established by a panel of aquaponics practitioners. The survey was approved under IRB Protocol No: 19-544 EX 1912 and distributed to educators through various aquaponics social media outlets and Extension email lists. Respondents were encouraged to share the survey with fellow aquaponic practitioners to increase the sample size.

Early in the survey, respondents were asked to self-identify as a hobbyist, producer, or educator, determining their stakeholder group. This research focuses solely on those that identified as educators (n = 117). The number of responses may differ for each analysis because respondents were not required to answer all questions leading to variability in sample size (n). Table 1 displays the distribution of teachers who self-identified as agriculture vs. non-agriculture and science vs. non-science as well as those that taught neither or both.

Table 1. Distribution of agriculture and science teachers.

Subject Area Taught	Frequency (n)
Agriculture	33
Non-Agriculture	21
Total	54
Science	19
Non-Science	35
Total	54
Either	34
Neither	11
Both	9
Total	54

We collected demographic information, years of teaching experience, years teaching with aquaponics, grade level and subjects taught, as well as perceived usefulness of aquaponics as a teaching tool. Educators were asked to self-identify their teaching responsibilities as agriculture (agriculture, horticulture, aquaculture, livestock, etc.), science (biology, chemistry, physics, physical science, etc.), vocational (welding, construction, shop, etc.), technology (engineering, computer science, etc.), math (algebra, geometry, statistics, etc.), or other. Respondents rated aquaponics' usefulness for teaching a variety of academic subjects (agriculture, biology, business, chemistry, English, ecology, food safety, math, physics, and social studies) and life skills (collaborative learning, creative problem solving, leadership, presentation skills, and responsibility). They also indicated their perception of student academic engagement when using aquaponics in the classroom. The data were analyzed using nonparametric tests (Kruskal Wallis, Mann-Whitney U, etc.) with IBM SPSS Statistics for Windows, Version 27.0.

Results and Discussion

Demographics

The self-identified educators that completed the demographics questions included 45 males and 14 females, and 1 preferred not to say. Most respondents identified as White (63%) followed by Black (10%), other (8%), Latino (7%), Asian (5%), and Native Hawaiian/Pacific islander (2%); 5% of respondents preferred not to disclose their race. The average number of years of teaching experience was 17.5 (± 12.3) (n = 56; range 0 to 40 years) including 5.0 (± 5.7) years teaching aquaponics (n = 50; range 0 to 30 years). More than half (52.1%) taught secondary students in grades nine through twelve and slightly more than one third (37.5%) of the respondents indicated they taught vocational or agriculture classes (Figure 1). Figure 2 shows the subject areas taught by the respondents.

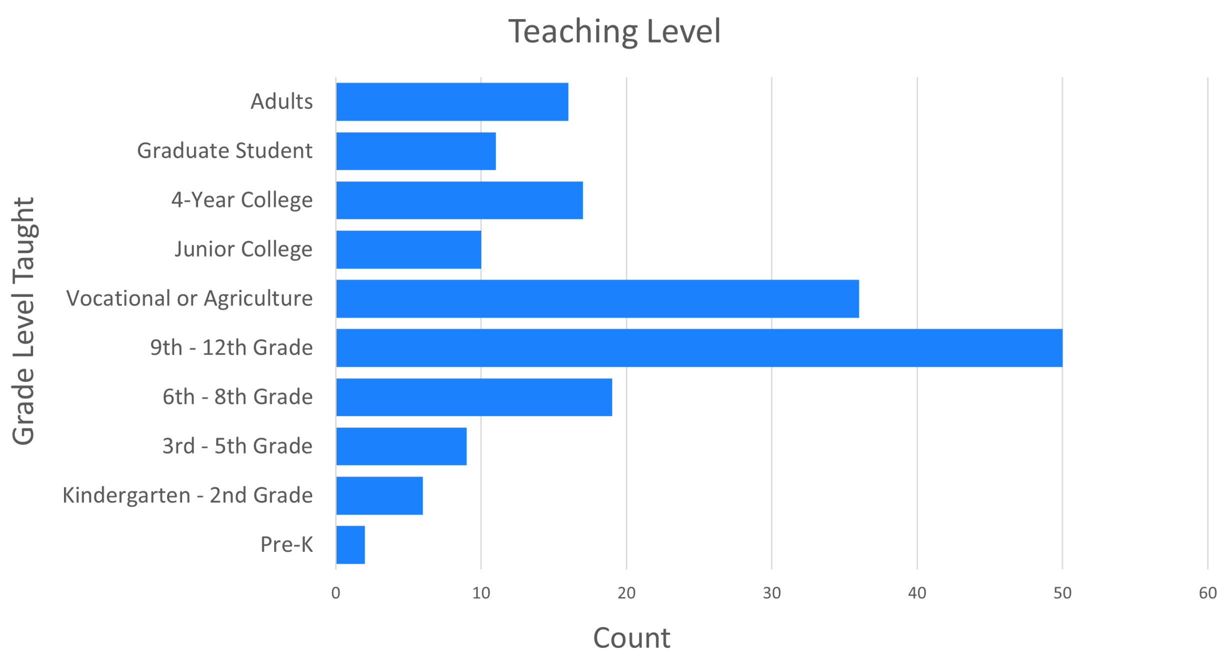

Figure 1. Respondent teaching level.

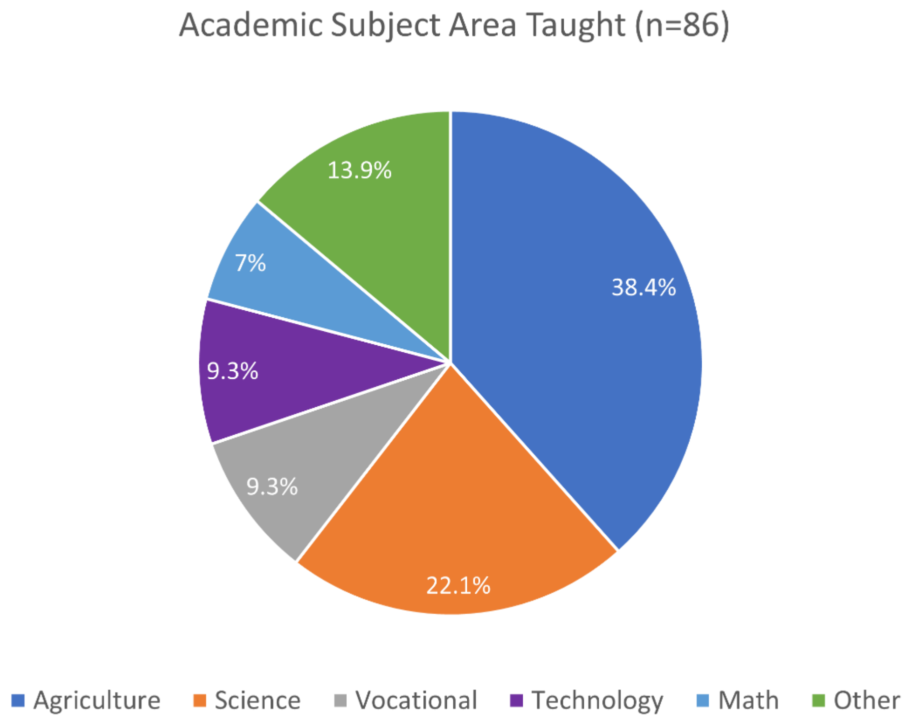

Figure 2. Self-identified teaching responsibilities indicated by respondents.

Perceived usefulness of tool – academic subjects

We asked teachers to rate the usefulness of aquaponics to teach a variety of subjects including agriculture, biology, business, chemistry, ecology, food safety, math, English, physics, and social studies. The median responses by subject area (1 = *Not Useful* to 5 = *Extremely Useful*) are presented in Figure 3. Aquaponics was rated *Moderately* to *Extremely Useful* for teaching a variety of STEM subjects, supporting findings reported elsewhere (Frederick, 2005; Hart et al., 2013; Johanson, 2009; Junge et al., 2019; Maucieri et al., 2018; Mazurkewicz et al., 2012).

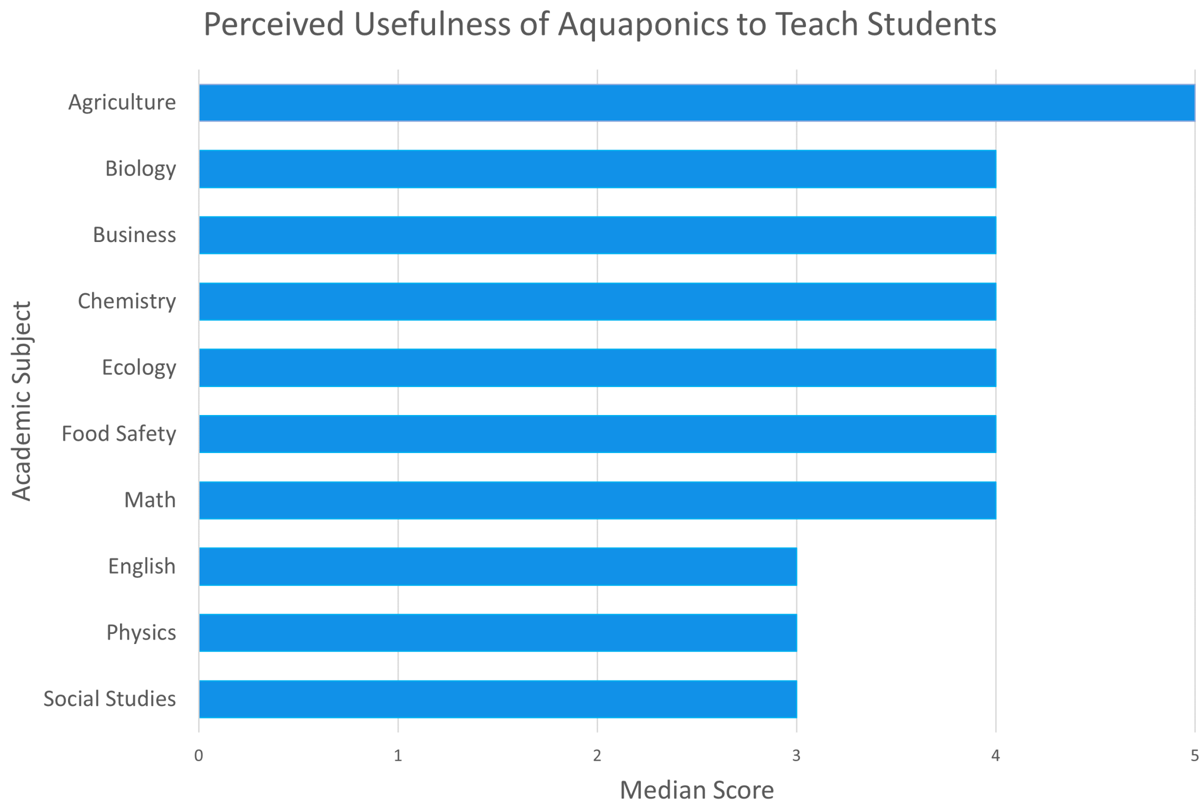

Figure 3. Median perceived usefulness of aquaponics to teach various academic subjects independent of discipline taught.

When we considered the perceived usefulness of aquaponics for teaching agriculture, those respondents who identified as an agriculture teacher considered aquaponics to be significantly more useful (Mdn = 5.0, IQR = 5.0 – 4.0) than non-agriculture teachers (Mdn = 4.0, IQR = 5.0 – 4.0; $p = .002$; $\eta^2 = .104$). Interestingly, we found that science teachers had significantly lower median perceived usefulness scores for teaching agriculture (Mdn = 4.0, IQR = 5.0 – 4.0; $p = .022$, $\eta^2 = .22$), math (Mdn = 3.0, IQR = 5.0 – 4.0; $p = .037$, $\eta^2 = .19$), and physics (Mdn = 3.0, IQR = 3.0 – 2.0; $p = .019$, $\eta^2 = .18$) compared to non-science teachers (Mdn 5.0, IQR = 5.0 – 4.0; Mdn 4.0, IQR = 5.0 – 3.0; Mdn 3.0; IQR = 4.0-3.0, respectively, Figure 4). The perceived usefulness of aquaponics for teaching the other academic subjects (e.g., biology, business, chemistry, ecology, food safety, English, and social studies) were not significantly different from each other and therefore not included in Figure 4. These findings suggest that science teachers overall have a lower perceived usefulness of aquaponics as a teaching tool.

Whether this is because they have tried and failed or are not thinking broadly enough about the application potential of aquaponics is unclear. There is a need for additional training opportunities and materials to ensure science teachers can fully capitalize on the utility of aquaponics for a broad range of science and mathematical applications (Pattillo et al., 2021a, b). This echoes the sentiment of Hart et al. (2013) who identified that providing teachers with ongoing teaching/learning materials is a key element to the successful integration of aquaponics in a classroom setting.

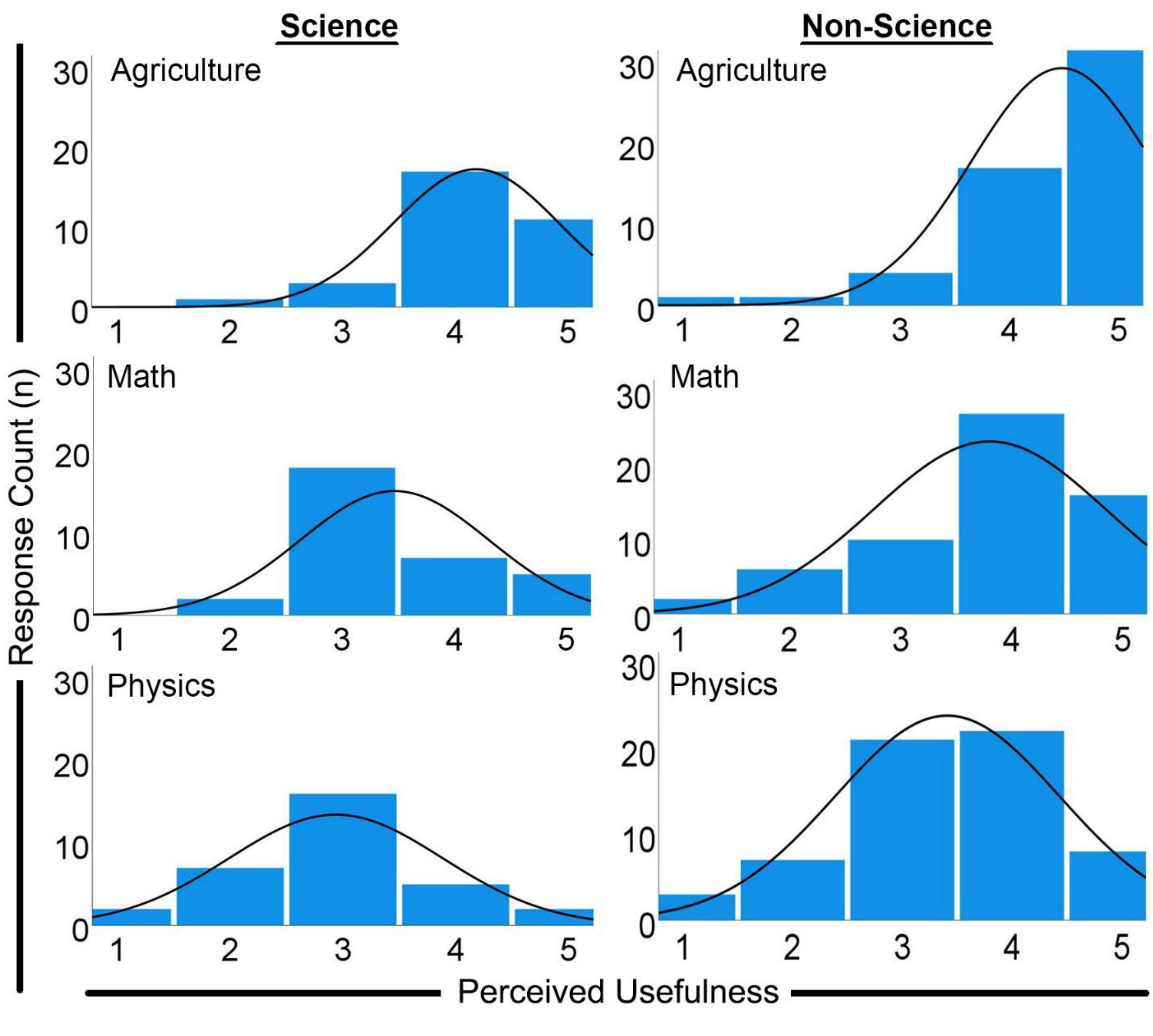

Figure 4. Perceived usefulness of aquaponics to teach agriculture, math, and physics among science and non-science teachers. Ratings were 1 = *not useful*, 2 = *somewhat useful*, 3 = *moderately useful*, 4 = *very useful*, 5 = *extremely useful*.

Time in teaching effect on perceived usefulness – academic subjects

To investigate time in teaching effect, we grouped teacher responses (n = 56) into early (0-5 years; n = 10), mid (6-15 years; n = 19), and late (16+ years; n = 27) career levels then determined each group's median perceived teaching usefulness score for teaching across all disciplines. Respondents who self-identified as agriculture teachers (n = 33) or science teachers (n = 19) exhibited no statistically significant difference among career levels (p = .618, η^2 = .23 and .722, η^2 = .19, respectively). These findings suggest that time in teaching did not have an impact on their perceived usefulness of aquaponics for teaching various subjects.

Perceived usefulness of tool – life skills

Several researchers have included various life skills (e.g. creative problem solving, responsibility, collaborative learning, leadership, and presentation skills) into their research questions. Conroy and Walker (2000) examined the integration of academic and vocational subject matter in the aquaculture classroom finding that both teachers and students gained valuable experience in responsibility beyond their academic studies. Hart et al. (2013) interviewed teachers who identified fun, developing responsibility, and compassion for living organisms as positive outcomes from using aquaponics in the classroom. We found that all respondents, independent of discipline, *Moderately* or *Strongly Agreed* that aquaponics is useful for teaching creative problem solving, responsibility, collaborative learning, leadership, and presentation skills (Figure 5).

Agriculture teachers reported a significantly lower perceived usefulness of aquaponics (Mdn = 4.0, IQR 4.0 – 5.0) to teach collaborative learning compared to non-agriculture teachers (Mdn = 5.0, IQR = 4.0 – 5.0; p = .047). No other significant differences were found between agriculture and non-agriculture for the remaining life skills considered ($p \geq .104$). As for science teachers, we found no significant differences for any life skills considered when compared to non-science teachers ($p \geq .06$).

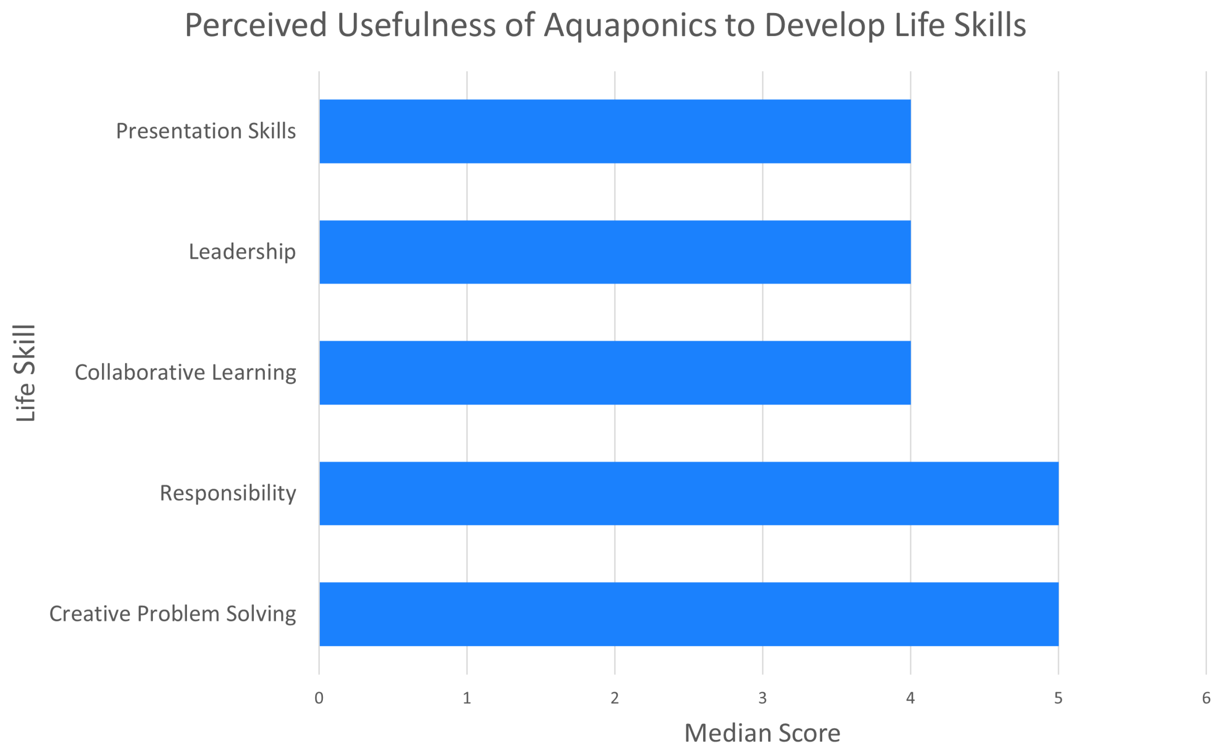

Figure 5. Perceived usefulness of aquaponics to develop life skills.

Time in teaching effect on perceived usefulness – life skills

We grouped teacher responses by their years of teaching experience as early (0-5 years; n = 10), mid (6-15 years; n = 19), and late (16+ years; n = 27) career levels. Agriculture teachers' (n = 33) perception of aquaponics for teaching responsibility were significantly different among career stages (p = .016). Post hoc, pairwise comparisons with a Bonferroni correction indicated a significant difference between early (Mdn = 5.0, IQR = 5.0 – 5.0) and late (Mdn = 4.0, IQR = 4.0 – 5.0) career agriculture teacher responses (p = .014). No other significant differences were found among career stages for the life skill responsibility ($p \geq .093$). Additionally, we found no significant differences among career stages for the remaining life skills considered ($p \geq .073$). Science teachers (n = 19) expressed no significant differences among career stages for any life skill measured ($p \geq .319$).

Aquaponics as a tool to engage students

Respondents were asked to indicate their perception of student academic engagement when aquaponics is used in the classroom environment (1 = *Strongly Disagree* to 5 = *Strongly Agree*). When considering all respondents (n = 50), we found a median perceived usefulness to engage students score of 4.0 (IQR = 4.0 – 5.0). These results support work by Junge et al. (2014) who found aquaponics was a successful and engaging way to teach systems thinking.

Agriculture teachers (n = 33) reported significantly lower perceived student engagement when compared to non-agriculture teachers (Mdn = 3.0, IQR = 4.0 – 2.0; Mdn = 4.0, IQR = 4.0 – 3.0; $p = .037$, $\eta^2 = .25$). This contradicts Wingenbach et al. (1998), who found that agriculture teachers perceived using aquaculture/aquaponics in the classroom motivated students. These findings warrant additional investigation to determine if a small sample size of non-agriculture teachers (n = 21) contributed to this finding. Should the reduced perception of student engagement among agriculture teachers be found reliable, further consideration of student engagement within aquaponics curriculum application, with emphasis on potential barriers, serves as an important next step in the research to ensure maximum student engagement.

We found no significant differences in perceived student engagement among career stage groups for respondents who identified as either agriculture or science teachers (p = .825 and .063, respectively).

Conclusions

Numerous studies have found that aquaponics is a beneficial teaching tool but there are barriers or hurdles to overcome in maximizing effectiveness (Pattillo et al., 2022). Survey respondents perceived aquaponics to be *Extremely Useful* for teaching agriculture and *Very Useful* for teaching a variety of other STEM topic areas. We found there is room for improvement in making connections between other, less intuitively connected, subject areas including social studies, English, and physics. While we found significant differences between teacher groups (non-agriculture/agriculture; and non-science/science), the general perception was that aquaponics is useful to teach various academic subjects and life skill categories, regardless of teaching experience level.

While we found perceived student academic engagement to be generally high, this varied by subject area taught. These findings suggest that there is opportunity to further improve student engagement using targeted trainings, enhanced program development, and increased system flexibility, all of which may be delivered through well designed Extension programming. More work is needed to evaluate the impact of sample size on student engagement. However, should future studies continue to support our findings, targeted Extension efforts may be useful in improving the perceived effectiveness of aquaponics as a teaching and student engagement tool.

These data were a part of a larger study aimed at aquaponics practitioners that includes educators. Conclusions are based on the assumption that the survey sample population is representative of the general educator population. However, we acknowledge a pre-existing interest in aquaponics among respondents. Further, the electronic delivery of the survey employed within this study may create a barrier of entry for potential respondents. Finally, respondents were not required to answer all questions in this study, therefore some data gaps exist (not all educators self-identified or responded to all academic subject areas). The data presented are intended to provide the most robust dataset while minimizing errors.

We recommend further research directed towards communicating the connection between aquaponics and the many tangential academic subjects. This includes the development and delivery of teacher support materials that connect desired learning outcomes, by subject area, with potential aquaponic applications. Extension is uniquely positioned to fill this gap.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Acknowledgements

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