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# Learning Outcomes in Sustainability Education Among Future Elementary School Teachers

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**Abstract**

Universities and colleges around the world are exploring ways of reorganizing curricula to educate future leaders in sustainability. Preservice teachers hold tremendous potential to introduce concepts of sustainability far earlier than post-secondary education. However, there is little research of such efforts to yield changes in future elementary school classrooms. This article shares a new, required course—Sustainability Science for Teachers (SSFT)—that is designed to present sustainability topics to preservice teachers. Using the course as a case, we ask: Do preservice teachers acquire skills and content knowledge in sustainability, and does that experience translate to elementary classrooms? Pre- and post-test data from 234 students and a follow-up survey with 103 respondents offers evidence towards addressing this question. Analysis shows preservice teachers gain skills in systems thinking and develop content knowledge in sustainability. This study suggests sustainability is being introduced into elementary classrooms after preservice teachers were required to take a course in sustainability.

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## INTRODUCTION

Around the world, the field of sustainability promises to enable students to recognize challenges and create lasting solutions for the future (Nolet, 2009). The United Nations Decade of Education for Sustainable Development brought sustainability to the forefront as a guiding concept for education across the globe in its 2005–2014 strategic plan (UNESCO, 2004). Sustainability places inter-generational equity, the vitality of Earth's processes and care for the world's poor at its core (Our Common Future, 1986). In response, universities and colleges are reorganizing their curriculum to support education for sustainability (EfS) (Nolet, 2013). Courses that address sustainability need to be constructed in a manner that fits with the local context and supports the professional development of the students (Crow & Dabars, 2015).

Despite three decades of dialogue, the concept of sustainability remains contested (Miller, 2013) and needs to be continually reconstructed to fit the socio-cultural setting within which learning occurs (Stauffacher, Walter, Lang, Wiek, & Scholz, 2006). Educators, deans and university officials are working to interpret sustainability in a variety of ways and, as a result, are co-creating the meaning of sustainability education (Trencher, Yarime, McCormick, Doll, & Kraines, 2014). Thus, sustainability is an emergent mission in higher education to prepare the next generation to solve problems in a complex and ever-changing world (Church & Skelton, 2010). Yet the United Nations is calling for sustainability to be introduced earlier than post-secondary education, during a child's formative learning years in elementary and middle schools (UNESCO, 2010). According to Nolet (2013), a shift in perspective towards the planet, people and production is underway such that 'Teacher education institutions can play a critical role in the work of reorienting education systems at all levels to address sustainability' (p. 53). Preparing preservice teachers with the content knowledge and skills to teach sustainability offers a way to transform society (Dillon, 2012; Tilbury, 2004). While this perspective maintains that the higher education focus for sustainability in the short term, the introduction of the topic to preservice teachers at the university level will fulfil the United Nations goal in the long term through the preservice teachers' future classroom leadership roles.

O'Byrne, Dripps and Nicholas (2014) reported that 200 universities created degree-granting programmes in sustainability. Yet only one listed programme dedicated specifically to teacher education (Prescott College) offers a degree in sustainability. Despite a lack of programmes, there are many ongoing efforts to integrate sustainability into preservice teacher education. For example, Australia incorporates sustainability into their national curriculum (AESA, 2014) and across Southeast Asia and the Pacific Islands; teaching sustainability is being experimented with across numerous programmes (Cheong, 2005; Effeney & Davis, 2013). In Europe, efforts to bring sustainability into teacher education are well under way (Jucker & Mathar, 2014), as also in South America and Africa (Tilbury, 2011). This array of global efforts

demonstrates a belief that equipping preservice teachers with sustainability knowledge, skills and attitudes will lead to the next generation being more informed and earlier than post-secondary education (Gough, 2013).

There is, however, a paucity of evidence on the efficacy of large-scale programmes that deliver sustainability education and evidence of what skills and content knowledge are gained. This study uses a new course, Sustainability Science for Teachers (SSFT), as a case study to add evidence along these lines. We ask: Do preservice teachers gain new skills and retain content knowledge in sustainability, and does that experience translate to sustainability education in elementary classrooms?

This question is an important first step to understanding whether efforts to educate preservice teachers in sustainability affect changes in future elementary school classrooms. The next logical questions delve into how those new skills and content knowledge are translated into elementary classrooms. Sustainability literacy among preservice teachers represents a change in how and what is taught in elementary schools. The following section introduces the course and reviews factors that influenced the course design.

## CASE STUDY COURSE: SUSTAINABILITY SCIENCE FOR TEACHERS

In 2011, the Mary Lou Fulton Teachers College (MLFTC) at Arizona State University (ASU), one of the largest teacher education programmes in the USA, designated sustainability as a required field of study for preservice teachers in the elementary education programme. The SSFT course was designed to introduce sustainability-based content knowledge through classroom and online learning activities with the long-range goal of impacting future elementary classrooms. The course was launched one year later in the fall of 2012.

SSFT aims to prepare preservice teachers with the skills and content knowledge necessary to teach their future kindergarten to eighth grade (K-8) students about sustainability. The content knowledge for the course is inspired by Gro Harlem Brundtland's 1986 report. The course defines sustainability as paying close attention to the Earth's natural limits, bettering life for the world's poor and meeting the needs of the present without compromising the needs of future generations. The course designers drew upon Kates et al. (2001) to demonstrate how science and sustainability can be mutually reinforcing. Content was adapted for preservice teachers from sources including sustainability literacy (Stibbe & Luna, 2009), principles for assessment (Gibson, 2006) and sustainable development (Sachs, 1997). An initial research project showed that preservice teachers obtained greater content knowledge in eight discrete categories (Foley, Archambault, & Warren, 2015; see Table 1). These eight 'categories' of content knowledge are used to support the evaluation of learning outcomes for this research.

Specific sustainability challenges, for example, waste reduction, were identified and preservice teachers were encouraged to construct collaborative solutions. Likewise, they were trained to translate these thought processes and action pathways into curricular events for their future classrooms. The course designers introduced

**Table 1** Content Knowledge Integral to Course Design and Identified as Reflected in Student Learning Outcomes in an Initial Pilot Research Project

| | **Categories of Learning Outcomes in Course Design** | **References** |
|---|---|---|
| 1 | Taking a disposition of awareness of problems | Orr, 1989 |
| 2 | Recognize challenges to socio-ecological viability and integrity | Rockström, Steffen, Noone, Persson, Chapin et al., 2009 |
| 3 | Consider intra-generational equity in contemporary decisions | Our Common Future, 1986 |
| 4 | Analyse problems as interconnected systems | Meadows, 2008 |
| 5 | Respect plurality in values | Shulman, 1986 |
| 6 | Identify material and resource loses and opportunities to conserve | Graedel and Allenby, 1996 |
| 7 | Design solutions that are responsive and adaptable changes | Rodin, 2014 |
| 8 | Construct strategic solutions; going beyond the education mission | Trencher et al., 2014 |

**Source:** Foley et al. (2015).

four ways of thinking that provided a landscape in which new knowledge about sustainability can be situated and identified sustainability topics that can be explored:

1. Comprehend and work to construct problems as interconnected 'systems' (Meadows, 2008);
2. Consider 'values' explicitly in contested settings (Solomon & Aikenhead, 1994);
3. Envision alternative 'futures' (Robinson, Burch, Talwar, O'Shea, & Walsh, 2011); and
4. Work towards 'strategic' interventions (Norton, 2005).

This supports a shift from problem framing to comprehensive solution strategies as a primary objective for the course (Warren, Archambault, & Foley, 2015). There are clear overlaps between sustainability content knowledge, attitudes and skills for teachers and their students, aligning closely with published sustainability competencies (Wiek, Withycombe, & Redman, 2011; Wiek, Bernstein, et al., 2016). The video *Big Themes of SSFT* provides an overview of the course and can be viewed online.[1]

The project team was built in a fashion that draws from Holdsworth and Thomas (2015) framework for curriculum development. The team was led by the director of research and development (Annie Hale), who drew upon expertise in the form of graduate students and faculty from the School of Sustainability and the School for the Future of Innovation in Society at ASU, and sought out support in pedagogical approaches for preservice teachers from the MLFTC. The director oversaw the

creation of the course by drawing upon a team with skills in graphic design, digital filmmaking and web development. The SSFT course was designed to occur over 15 weeks and progress through topics ranging from population, poverty and food to educational change. The course's hybrid format requires preservice teachers to watch short (~10 minute) documentary-style, narrative-driven videos in modules that are approximately 75 minutes per topic week. After engaging with the videos, preservice teachers are expected to use their newly acquired content knowledge in the face-to-face college classroom once per week. During the 75-minute class period, students work collaboratively to identify ways to translate the material to their future classrooms through hands-on, project-based activities.

Preservice teachers track their learning with a variety of assessments such as quizzes and reflections. The course reaches students across ASU's four campuses and is taught by a dedicated and engaged group of instructors who use agreed upon materials. This ensures that the course material is consistent regardless of location or instructor. Every semester, revisions continue to be made on an ongoing basis, as part of an iterative cycle to improve the course, based on student and instructor feedback (Archambault & Warren, 2016).

The course objective is to instil K-8 teachers with sustainability literacy and to prepare them to translate sustainability concepts into their future classrooms. K-8 educators are often overlooked when it comes to large-scale investments, mainly because they are generalists teaching a broad range of subjects, including language, arts, math, social studies and science. Even though they cover a multitude of topics, K-8 teachers are the leaders who instil passion and awe in young minds before students might be turned off to pursuing science content in secondary schools. Preparing a society literate in sustainability requires innovative ways to share knowledge, identify values and address current and future challenges, even from the youngest minds (Rodin, 2014; Stibbe & Luna, 2009).

## RESEARCH DESIGN

This research offers a case study designed to bring evidence to bear on the question: Do preservice teachers gain skills in systems thinking and retain content knowledge in sustainability and does that experience translate to the sustainability education in elementary classrooms? Learning outcomes, in terms of systems thinking, skills development and content knowledge, were measured with pre- and post-concept maps, discussed below. An online survey tool was used to capture data on how learning outcomes are being translated into practice.

To assess learning outcomes from the SSFT course, a random sample of 234 preservice teachers was taken to represent the total population of 687 preservice teachers that matriculated between fall 2012 and spring 2014 and completed the requisite materials. The sample size supports statistical results with 95 per cent confidence and 3 per cent margin for error when sampling a small population (Sudman, 1976). In addition, a survey instrument captured responses from 105 persons from a population of 300 persons who matriculated from the course between fall 2012 and fall 2013, representing a 35 per cent response rate, which is acceptable for web-based

**Table 2** Demographic Data for Total and Sample Populations

| | **Total Population*** | **Sample Population** |
|---|---|---|
| Race | 36% (Non-white) | 33.5% (Non-white) |
| Gender | 77% (Female) | 90.1% (Female) |
| Marital status | Not reported | 81.4% (Single) |
| Age | Not reported | 22.6 (Std. Dev. = 4.73) |

**Source:** MLFTC (2014).
***Note:** Demographic data for total population reported in the 2013–2014 MLFTC Annual Report.

surveys (Manfreda, Bosnjak, Berzelak, Hass, & Vehovar, 2008; Shih & Fan, 2008). To assure anonymity, participants were assigned a number ordered by year, semester, classroom instructor, and last and first names. Basic demographic data was captured at the time when students enrolled in the course (see Table 2). The sample population is representative of the overall student population within MLFTC, even with more female preservice teachers (90.1%) in the K-8 (elementary school) programme as compared to the total population of women in MLFTC (77%).

## LEARNING OUTCOMES: AN EVALUATION OF NEAR-TERM SKILLS ACQUISITION AND CONTENT KNOWLEDGE

Grades are not a strong measure of learning outcomes, since students can enrol in a course and already have the ability to attain the highest possible grade (Tucker & Courts, 2010). Thus, learning outcomes were evaluated between pre- and post-tests to investigate three research questions:

A. Do preservice teachers broaden their definition of sustainability at the conclusion of the course using the change in 'nodes' and 'connections' on the concept maps as indicators?
B. Do preservice teachers express greater complexity in the 'structure' of sustainability at the conclusion of the course using levels of hierarchy in the concept maps as an indicator of systems thinking?
C. Do preservice teachers demonstrate greater content knowledge of sustainability as measured by the expression of 'categories' on the concept maps as indicators of content knowledge?
D. How willing are graduates of SSFT course to teach sustainability in their current classrooms?

The first two research questions, taken together, offer measures of systems thinking through the connection of additional nodes and increasing complexity in their concept maps. The third research question is of critical importance to understand the development of content knowledge. Together, these measures will offer data on the ability of preservice teachers to demonstrate greater complexity in systems thinking

and content knowledge. The last research question is more exploratory and relies upon survey data. Next, we explain what concept maps are and how we used them to gather data.

Concept maps are a two-dimensional image created by each participant using key words (nodes) and linking phrases (connections) to express a complex, encompassing concept (Patton, 2008). Concept maps are not constrained by grammatical limitations found in long-form narratives and essays. They outperform multiple-choice tests in the evaluation of emergent concepts, in which there is no 'perfect' answer (Ifenthaler, 2010; Novak, 1990). Murdy, Weber and Legge's (2011) asserted concept maps can interrogate the meta-cognitive processes that structure student knowledge acquired during a course of study. Nesbit and Adesope (2006) documented more than 500 peer-reviewed articles featuring 'concept maps' or 'knowledge maps' as evidence of course learning between pre- and post-tests. The use of concept maps as an assessment tool is a well-established practice.

Preservice teachers were shown a sample concept map not related to sustainability and then given a blank piece of paper and pencil, an acceptable format given pragmatic constraints (Muryanto, 2006). Participants were allowed 20 minutes to complete the concept map, which is considered an optimal time period for completing the exercise (McClure, Sonak, & Suen, 1999). The pre-test prompt stated:

1. Have you heard of the term sustainability prior to registering for this course? Yes or No?
2. If so, how do you define the term sustainability?
3. Create a concept map that depicts the idea of sustainability.

On the last day of class, the preservice teachers responded to a prompt that stated:

1. After taking the course, how do you define the term sustainability?
2. Were the four ways of thinking structured by the Sustainability Education Framework for Teachers (SEFT) useful for considering the complex topics discussed in this course? Which of the ways of thinking were most helpful to you? Why?
3. Create a concept map that depicts the idea of sustainability.

The prompts asked participants to define one word, 'sustainability', making it a minimally-directed task (Yin, Vanides, Ruiz-Primo, Ayala, & Shavelson, 2005), which more accurately reflects participant's knowledge than highly-directed tasks (Ruiz-Primo, Schultz, Li, & Shavelson, 2001). Our research did not evaluate 'validity' or 'relevance' against expert-derived concept maps, a strategy performed by Shallcross (2016) to assess 'correctness' or goodness of fit to learning objectives. To the contrary, we sought to understand the students' representation of sustainability, as it remains an emergent theory and is continually (re)constructed, even among experts (Miller, 2013).

Prior to analysis, two research assistants (with no role in coding) removed all unique identifiers and numbered the concept maps. Pre-test concept maps were analysed separately from post-test concept maps by one researcher who coded the maps first, while a second researcher reviewed the coding. Discrepancies were

negotiated and consensus was reached for all codes by the three researchers (Miles & Haberman, 1994). All concept maps were analysed for total nodes and connections as interval variables for statistical analysis, using paired t-test within individuals to address research question A.

Kinchin, Hay and Adams (2000) provide three hierarchical levels of system-level structure that can be depicted in creating concept maps: (a) 'spoke and wheel' with no hierarchy; (b) 'chain-link' with many levels of hierarchy, but expressing linearity; and (c) 'net' with several levels of hierarchy and connections between branches. Turns, Atman and Adams (2000) interpreted 'nets' as 'decentralized' structures with 'cross-links', expressing dynamic feedbacks that interrupt hierarchy. Following McClure et al. (1999), we employed 'structure' as a measure for complexity. While this does not reflect the full nuances associated with complexity, yet it captures a quantifiable measure of complexity from centralized spoke (no hierarchy) to multiple levels of hierarchy to decentralized with cross-links expressing feedback loops. Researchers analysed 'structure' as follows: 0 = no hierarchy (spoke and wheel); 1 = primary and secondary levels of hierarchical structure (limited hierarchy); 2 = multiple levels of hierarchical structure (advanced hierarchy); and 3 = multiple levels of hierarchy with cross-connections (decentralized). We analysed the difference in 'structure' between pre- and post-test concept maps with paired t-tests within individuals and, thus informed research question B.

The content knowledge in the concept maps was handled in a manner similar to Shallcross (2016) by using the eight categories identified and briefly defined in Table 1. However, rather than using a linear scale from 0 to 8 with a mark on the scale for each category and measuring content knowledge by category, the research team aggregated data to measure content knowledge acquisition. Thus, we followed Stewart's (2012) scale to capture the depth of understanding in content knowledge: 0 = no understanding; 1 = basic understanding; 2 = strong understanding; and 3 = deep understanding. Following that scale, researchers coded categories as follows: 0 = no categories expressed; 1 = 1 to 3 categories expressed; 2 = 4 to 6 categories; and 3 = > 7 categories. Levels of content knowledge were analysed for differences of means (paired t-test within individuals) to answer research question C.

## TRANSLATION TO PRACTICE: WILLINGNESS TO BRING SUSTAINABILITY INTO THE K-8 CLASSROOM

In spring 2014, an investigation was conducted to understand the likelihood that sustainability literacy would 'translate to practice'. This was not designed to be a rigorous measure of long-term outcomes. Rather, this initial investigation and the data gathered therein offered suggestions for future survey designs and afforded the course designers feedback on the retention and recognition of materials. To address research question D, we deployed an online survey that asked course graduates:

1. To what extent have you incorporated the teaching of sustainability concepts within your current curriculum?
2. If you were granted access to all the videos, materials and coursework from your sustainability class, would you find these resources useful?

These questions sought to capture data on the likelihood that individuals have already translated sustainability content into practice (question 1) and explored if they would draw upon materials from SSFT, if they were offered greater access to the course content postgraduation (research question D).

## BOUNDARIES AND SCOPE

This study draws clear boundaries that inform the scope of this article. First, we only investigated the preservice teachers' skill development in systems thinking, which is but one of the four ways of thinking that are part of the course (Warren et al., 2015). Thus, this research offers no evidence on the ability of the preservice teachers to recognize a plurality of values, consider futures or craft strategic solutions. Second, the research focuses, analytically, on the eight categories of content knowledge derived from the pilot study, rather than employing an open coding schema. Third, the survey was an exploratory tool to understand the important question of translation to practice. These boundaries are revisited in the 'limitations' section and suggest avenues for further research. While this article is not a conclusive statement on the course's efficacy, nor does it demonstrate impacts on classroom practices, it evaluates the near-term outcomes that resulted from the addition of sustainability as a required course in the largest preservice teacher programme in the USA.

## RESULTS

The findings suggest that preservice teachers gain skills in systems thinking, as evidenced by an increase in the nodes and connections and level of complexity in the concept map structures, and demonstrate greater content knowledge after completing the SSFT course. Furthermore, the exploratory survey reports that 60 per cent of the 105 respondents have already brought sustainability into their K-8 classrooms. This suggests that as preservice teachers gain skills and content knowledge in sustainability, it affords them the willingness to teach sustainability in their elementary and middle-school classrooms. This case study shows that an intervention in preservice teacher education holds promise, when it comes to introducing sustainability earlier in a child's learning experience. The balance of this section reports on the specific findings for each research question.

A: Do preservice teachers broaden their definition of sustainability at the conclusion of the course, using the change in 'nodes' and 'connections' on the concept maps as indicators?

The paired t-test analysis of nodes and connections shows significant change for the preservice teachers (Tables 3–4). Total nodes increased by an average 8.46 ($p = < 0.001$), while connections increased by an average of 8.34 ($p = < 0.001$). The average preservice teacher more than doubled the number of nodes and connections. To put this finding into context, a similar research programme focused on learning outcomes for sustainability demonstrated a shift in the average number of concepts (nodes) from an average of 7 to 12, as measured by Segalas, Ferrer-Balas and

**Table 3** Results of the Pre- and Post-tests on Number of Nodes

| Test | *n* | Mean | Std. Err. | Std. Dev. | 95% Conf. Interval | |
|---|---|---|---|---|---|---|
| Pre-test | 234 | 7.43 | 0.243 | 3.72 | 6.95 | 7.91 |
| Post-test | 234 | 15.89 | 0.519 | 7.94 | 14.87 | 16.91 |
| Combined | 468 | 11.66 | 0.347 | 7.50 | 10.98 | 12.34 |
| Difference | | **8.46** | 0.573 | | 7.34 | 9.59 |
| Difference = Mean (Pre-test) – Mean (Post-test) | | | | **t = 14.76*****| | |

**Source:** Authors' own.
**Notes:** *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$. The bold values specify that the finding is significant.

**Table 4** Results of the Pre- and Post-tests on Number of Connections

| Test | *n* | Mean | Std. Err. | Std. Dev. | 95% Conf. Interval | |
|---|---|---|---|---|---|---|
| Pre-test | 234 | 6.99 | 0.263 | 4.02 | 6.47 | 7.51 |
| Post-test | 234 | 15.32 | 0.553 | 8.46 | 14.23 | 16.41 |
| Combined | 468 | 11.15 | 0.361 | 7.82 | 10.44 | 11.86 |
| Difference | | **8.34** | 0.612 | | 7.12 | 9.53 |
| Difference = Mean (Pre-test) – Mean (Post-test) | | | | **t = 13.60*****| | |

**Source:** Authors' own.
**Notes:** *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$. The bold values specify that the finding is significant.

Mulder (2008). These results are not directly comparable as Segalas et al. (2008) aggregated data from different courses that focused on engineering students, not preservice teachers. Yet our data align with those findings and suggest an equivalent learning outcome.

This measure alone only indicates that a greater number of nodes and connections were expressed on the concept maps after students completed the course, and does not necessarily indicate an increase in students' content knowledge. Thus, content knowledge expressed in the concept maps is imperative and is discussed further. Nevertheless, the high level of significance affords us confidence in asserting that the preservice teachers are assimilating new knowledge and cognitively aligning it through systems thinking with the concept of sustainability.

B: Do preservice teachers express greater complexity in the 'structure' of sustainability at the conclusion of the course using levels of hierarchy in the concept maps as an indicator of systems thinking?

The complexity in terms of 'structure' was observed to increase by 0.611 ($p = < 0.001$) levels of hierarchy for the average preservice teacher (Table 5). Students are more likely to conceptualize sustainability as a complex system with multiple levels of hierarchy, feedback, mutually reinforcing constructs and positive feedback loops. This shift in their representational maps suggests a greater comprehension for the complexity of sustainability and demonstrates skills development in systems thinking (Zhang, Soergel, Klavan, & Oard, 2008). Understanding complex systems is a core part of sustainability literacy and is defined as a core sustainability competency

**Table 5** Results of the Pre- and Post-tests on Levels of Hierarchy

| Test | *n* | Mean | Std. Err. | Std. Dev. | 95% Conf. Interval | |
|---|---|---|---|---|---|---|
| Pre-test | 234 | 1.62 | 0.056 | 0.858 | 1.5 | 1.73 |
| Post-test | 234 | 2.23 | 0.040 | 0.611 | 2.15 | 2.31 |
| Combined | 468 | 1.92 | 0.037 | 0.804 | 1.85 | 1.99 |
| Difference | | **0.611** | 0.069 | | 0.476 | 0.746 |
| Difference = Mean (Pre-test) – Mean (Post-test) **t = 8.88*** ** | | | | | | |

**Source:** Authors' own.
**Notes:** *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$. The bold values specify that the finding is significant.

**Table 6** Results of the Pre- and Post-tests on Levels of Content Knowledge

| Test | *n* | Mean | Std. Err. | Std. Dev. | 95% Conf. Interval | |
|---|---|---|---|---|---|---|
| Pre-test | 234 | 2.63 | 0.043 | 0.651 | 2.54 | 2.71 |
| Post-test | 234 | 1.88 | 0.052 | 0.790 | 1.77 | 1.98 |
| Combined | 468 | 2.25 | 0.038 | 0.815 | 2.18 | 2.33 |
| Difference | | **0.752** | 0.067 | | 0.621 | 0.883 |
| Difference = Mean (Pre-test) – Mean (Post-test) **t = 11.24*** ** | | | | | | |

**Source:** Authors' own.
**Not es:** *** $p < 0.01$, ** $p < 0.05$ and * $p < 0.1$. The bold values specify that the finding is significant.

(Wiek et al., 2011). The course resulted in the preservice teachers having a greater comprehension of sustainability as a complex system.

C: Do preservice teachers demonstrate greater content knowledge of sustainability as measured by the expression of 'categories' on the concept maps as indicators of content knowledge?

The average preservice teacher increased their content knowledge by 0.752 levels ($p = < 0.001$) (Table 6). This means that if a student entered the course and their concept map scored '0', they would, on an average, get close to a basic understanding, scored '1'. While preservice teachers who entered the course with a basic understanding (scored '1'), they would leave the course with a strong understanding (scored '2'). These results are encouraging in that they demonstrate an elevated level of content knowledge, which complements the greater number of nodes, connections and greater complexity observed on the concept maps.

D: How willing are SSFT graduates to teach sustainability in their current classrooms?

The survey results offer motivation for future research. Respondents to the online survey reported that they had incorporated sustainability into their courses 'somewhat' (53.9%) and 'extensively' (6.8%). This suggests that over 60 per cent of respondents are introducing sustainability into their classrooms. A larger number of the 105 respondents (92%) stated that if they were granted access to the course materials,

then they would find it useful in their current positions. This suggests that increasing the accessibility of the SSFT course materials will increase the incorporation of sustainability into elementary and middle-school classrooms.

## DISCUSSION

The preservice teachers matriculating from the SSFT course demonstrated systems thinking, expressed greater content knowledge and many reported they are introducing sustainability into their elementary and middle-school classrooms. This is heartening as the goal of the course is for preservice teachers to take the course material and bring it into their future classrooms, thus having an impact on the next generation. It suggests that investments in preservice teachers will pay dividends in the next generation who are just now entering elementary school classrooms.

## CONTRIBUTION TO THEORY BUILDING FOR SUSTAINABILITY IN HIGHER EDUCATION

Sustainability is a way to view the world and engage with the challenges before us; from water pollution to poverty. Scientific thinking can help to organize knowledge, which can be mobilized to solve these complex problems. K-8 educators are a valuable stakeholder group with whom to work because they are the leaders who instil passion and awe in young minds before science topics are deemed too complicated or boring in higher grades. Unfortunately, research has indicated that many K-8 grade educators feel unprepared and uncomfortable teaching science topics, such as sustainability, with their students because they have not been adequately prepared to do so (Howitt, 2007; Westerback, 2006). By supporting K-8 educators with an understanding of sustainability, we know that we will boost their confidence when it comes to teaching science topics that require the pedagogical and content knowledge needed for them to be successful in teaching these concepts (Shulman, 1986). The course, SSFT, is an intervention that aims to overcome some of these known roadblocks and foster a greater understanding and curiosity for science topics that confront the sustainability challenge. More often than not, those topics are addressed in secondary science teachers. By engaging K-8 educators with the necessary knowledge, skills and attitudes to implement sustainability concepts with their young students, we work towards the larger goal of preparing future generations to better handle the complex challenges facing our planet and collaboratively craft solutions.

## RESULTS IN CONTEXT: SCALE AND GENERATIONAL SHIFTS

It is important to situate these results in the context of the MLFTC at ASU, which is one of the largest teacher education programmes in the USA with a total of 1,683 graduates in 2013–2014 (MLFTC, 2014). Prior to the SSFT course, sustainability may have been a topic in some courses, but was not a core component of the teacher preparation programme at ASU. Today, this course is required for all preservice teachers

specializing in elementary education, including programmes focused on gifted youth, STEM for elementary students, bilingual and English as a second language. Not every preservice teacher at ASU is a 'willing learner', and since SSFT is required for graduation, it should be noted that it is common for preservice teachers to challenge the course instructors. Such challenging statements and in-depth discussions between the preservice teachers and course instructors on the relevance of the material to themselves as citizens and as future educators often arose and needed to be addressed directly. These 'healthy' negotiations are often the 'turning point' for many preservice teachers and highlight the inherent tensions of introducing more science topics, such as sustainability, as required course material. As such, 'turning points' need to be examined in greater depth and with alternative methods. While many universities are building stand-alone courses and programmes that introduce their student body to sustainability, for example, the valiant efforts at University of British Columbia in this direction (Marcus, Coops, Ellis, & Robinson, 2015), there is a need to infuse sustainability into existing programmes that contribute to how society is shaped, such as urban planning, teacher education and others with such professional foci.

## LIMITATIONS

This study represents but one example of how teacher education programmes can bring sustainability into their curriculum and the learning outcomes. Our analysis lacks a control or other comparative measure for success. Yet, a lack of control is often the case when sweeping curriculum changes are made. A third-party test for content knowledge of sustainability, such as the one offered by Sulitesst.org, may have offered a way to benchmark the concept map results against a more standardized testing format. The incorporation of other measures of content knowledge and measures of proficiency in the core skills taught in the course remain an open area of investigation.

This study attends to systems thinking by bringing evidence to bear from concept maps; however, our research does not address the preservice teachers' skills in values, futures or strategic thinking. The results in terms of content knowledge are constrained by the eight categories and analysis based on Stewart's (2012) levels of knowledge acquisition. There are methodological limitations to concept maps, specifically in regard to inter-rater reliability. Rather than dedicating the resources to have three persons code every record for the data, a second researcher cross-checked the original coding work and found a less than 5 per cent discrepancy rate within that sub-sample, an acceptable rate of inconsistency (Hallgreen, 2012). The aggregate average for the categories and structures is slightly skewed downward by those students whose pre-test were coded as '3', and thus demonstrated no measureable improvement in those particular areas. For this reason, an expanded or extended scale may offer a higher level of top-end granularity in future assessments. In addition, the survey tool was exploratory in nature. The data may be skewed by positive response bias and, again, it lacks a strong control group, for example, current elementary school teachers who did not take the SSFT course. Nonetheless, we remain confident in our research design and the study results.

In terms of sustainability education, the course was not designed to take the preservice teachers into 'real world' current event problem contexts, to attempt to grapple with those challenges unfolding right now. This stands in contrast in many ways to the current thinking on connecting sustainability education across the curriculum (Coops et al., 2015). This course was designed to build the preservice teachers' proficiency in four skill areas (futures, values, systems and strategic thinking) and content knowledge in other categories. As Duggan, Smith and Thomsen (2013) articulated, there will be barriers as EfS is scaled into elementary classrooms; from administrative, school board, parents' perceptions to teachers' own willingness to align classroom activities with sustainability. This leads to questions about how, exactly, these lessons are being translated into practice.

## FUTURE RESEARCH DIRECTIONS AND NEXT STEPS

Though the results of our evaluation are compelling, research is needed to follow the preservice teachers into their future classrooms to describe, analyse and assess how they implement sustainability. As part of that effort, we invite scholars to build a robust network to investigate this topic around the world and to form a community of shared learning. We welcome researchers who are interested in connecting with former preservice teachers, such as Laurie Dutton, who was recently named the 2014 Outstanding Teacher Candidate for the MLFTC (Lucus, 2014). Her experience within the course and how she is applying those lessons learned into her first classroom can be viewed at http://tinyurl.com/ldasu. We believe that Laurie's story (and many others) need to be collected and analysed. Laurie's story also could be indicative of many students who expressed initial hesitation at the beginning of the course before experiencing a 'turning point'. These early rounds of feedback and evaluation, as well as future research, will inform our ongoing efforts to make the SSFT course more impactful. Work remains to design and deploy a more robust survey instrument that can offer more externally valid data on the translation of sustainability content into the classroom.

## CONCLUSION

Sustainability is a global as well as a local issue that is intricately interwoven and interdependent with every Earth system that sustains humankind. Elementary and middle-school educators are an essential social group that will be responsible for carrying forward the lessons of sustainability to the next generation at a most impressionable age. College-level coursework related to teaching sustainability is desperately needed as part of twenty-first century teacher preparation programmes (Carney, 2011; Feinstein & Kirchgasler, 2015; Nolet, 2009). Education is a catalyst for change, and preservice teachers are a promising means to achieving large-scale social transformation and better prepare the next generation. If the topic of sustainability is provided to preservice teachers in tangible, relevant coursework, they will take up that content knowledge and use it in their future classrooms. These initial efforts need

to be followed up with systematic research that explores the barriers and enabling conditions that affect the introduction of sustainability into elementary and middle schools. Preservice teachers are continuously seeking ways to make a difference and impart a positive change in the lives of their students. The SSFT course supports learning outcomes that prepare preservice teachers to enter the global village of the twenty-first century with an increased literacy concerning the major challenges of our time and a willingness to take those lessons into their classroom.

## Note

1. See http://sse.asu.edu/ways-of-thinking/

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