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Development of Scientific Thinking Facilitated by Reflective Self-Assessment in a Communication-Intensive Food Science and Human Nutrition Course

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Abstract

A one-credit seminar on controversies in food science and human nutrition was a platform to introduce students to learning frameworks for thinking-like-a-scientist. We hypothesized that explicitly engaging students in thinking about their thinking abilities within these frameworks would enhance their self-perception of scientific thinking, an important general ability for food scientists. Our objectives were to assess thinking-like-a-scientist using a student self-assessment survey, and analyze their self-reflections for evidence of such thinking. For students enrolled in one of the offerings of this course among five semesters from 2012-2014, differences in scores on a survey instrument for thinking-like-a-scientist from the beginning to the end of the course showed gains in self-assessed abilities (N = 21-22 students/semester). In each of the first 2 semesters in which we introduced thinking-like-a-scientist frameworks, students thought they were better at defining problems scientifically by 13-14%. In the third course offering, students' self-assessment of their abilities to seek evidence improved by 10%. In the fourth and fifth semester course offerings, students' self-assessed abilities to develop plans based on evidence improved by 7-14%. At the end of each semester, students' self-reflections on scientific thinking (N = 20-24/semester) included specific reference to asking questions (45-65% of reflections) and making plans based on evidence (26-50% of reflections). These data support the usefulness of self-reflection tools as well as specific learning frameworks to help students to think about and practice thinking-like-a-scientist.

Keywords

scientific thinking, assessment, reflection, survey, pedagogy

Disciplines

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Development of scientific thinking facilitated by reflective self-assessment in a communication-intensive food science and human nutrition course.

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Scientific thinking and self reflection (Research)

Abstract

A one-credit seminar on controversies in food science and human nutrition was a platform to introduce students to learning frameworks for thinking-like-a-scientist. We hypothesized that explicitly engaging students in thinking about their thinking abilities within these frameworks would enhance their self-perception of scientific thinking, an important general ability for food scientists. Our objectives were to assess thinking-like-a-scientist using a student self-assessment survey, and analyze their self-reflections for evidence of such thinking. For students enrolled in one of the

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offerings of this course among five semesters from 2012-2014, differences in scores on a survey instrument for thinking-like-a-scientist from the beginning to the end of the course showed gains in self-assessed abilities (N = 21-22 students/semester). In each of the first 2 semesters in which we introduced thinking-like-a-scientist frameworks, students thought they were better at defining problems scientifically by 13-14%. In the third course offering, students' self-assessment of their abilities to seek evidence improved by 10%. In the fourth and fifth semester course offerings, students' self-assessed abilities to develop plans based on evidence improved by 7-14%. At the end of each semester, students' self-reflections on scientific thinking (N = 20-24/semester) included specific reference to asking questions (45-65% of reflections) and making plans based on evidence (26-50% of reflections). These data support the usefulness of self-reflection tools as well as specific learning frameworks to help students to think about and practice thinking-like-a-scientist.

Key words: scientific thinking, assessment, reflection, survey, pedagogy

Introduction

A core ability for food science professionals is the ability to communicate scientific information to clients, including other scientists, managers, and the public. Underlying the ability to communicate scientific information is the ability to think like a scientist. Thinking-like-a-scientist is a process in which we: 1) ask questions, 2) define a problem scientifically, 3) seek evidence, 4) make decisions based on evidence, 5) consider implications and applications of decisions, and 6) revise and reflect (Williams and others 2004). Food science professionals need to ask questions, seek evidence, plan thoughtfully, and interpret, reflect and revise constantly.

This approach to thinking is a key standard of professionalism that food science educators must help students achieve and value as an enduring habit for food scientists. Food science students participate in laboratories in which they record observations, apply trial and error, apply critical thinking and use credible sources of information. In food science professions, performing and analyzing experiments, collecting and evaluating quality assurance data and determining evidence-based approaches to food manufacturing problems are a few examples of the abilities to think-like-a-scientist.

Defining scientific thinking and best practices for scientists, while crucial, is not easy. Babbie articulated a key issue as he observed that objectivity and reality are only approximated by human agreement, i.e., intersubjectivity. Human agreement about reality can be supported by careful measurements using reliable and valid devices insofar as possible, and by processes of rigorous peer review (Babbie 2005). Scientism, a belief that discovering and using facts is a preferred approach to resolving controversy, continues to be central to decision-making, even though facts are often in dispute and political sides may ignore inconvenient aspects of existing data (Kleinman 2009). A belief in technological progress, the superior ability of new approaches to gathering information and interpreting the world in decision-making is also taken for granted (Kleinman 2009). We contend that it is crucial for scientists to practice science rather than express a belief in the value of science and technological progress. Social constructionism (Burr 2015) is a necessary perspective that scientists need to include in their practices while seeking reliable information.

The process of educating students is inherently social. We need to be vigilant not to take “truth” or observed reality for granted. We need to help students appreciate that. Social constructionism reminds us always to remain skeptical and critical. Food scientists need to take differing perspectives on science into account as they navigate careers in which they will always encounter controversial issues. New scientific data are always emerging and new technologies developing. Society must weigh carefully social costs and benefits. Thinking-like-a-scientist offers a framework that may help us confront and manage an always-changing world.

The co-authors of this paper were informed by a thinking-like-a-scientist construct (Williams and others 2004). Scholars of critical thinking also informed this work. Brookfield (1987) describes a process of questioning assumptions, researching and seeking multiple perspectives on those assumptions, and making decisions based on the assembled evidence and perspectives (Brookfield 1987). The process of reflective judgment was also considered, in which reflective thinkers use evidence and reason to support their judgment (King and Kitchener 2004). We tried to apply thinking-like-a-scientist authentically to a range of everyday problems. We wanted to make thinking-like-a-scientist even more accessible to students who do not necessarily see themselves as scientists. Often students seem to think of scientific thinking as what occurs in their laboratory courses or in the research laboratories of their professors, rather than as something that has value in everyday life when transferred into any decision making/problem solving context. Through a series of discussions of our thought processes in approaching everyday problems, we created a thinking-like-a-scientist construct modified from Williams and others (2004) that includes a 4-step process in which we:

1) ask questions about what is going on around us,
2) gather evidence to try to explain situations/problems,
3) develop plans based on evidence and reasoning to address situations/problems,
4) interpret how our plans worked.

This four-step process alludes to the scientific method (McPherson 2001). Asking questions and gathering evidence imply a process of formulating and testing hypotheses (proposing possible explanations for an observation, designing, conducting and analyzing hypothesis-testing experiments). We might well assess students' learning of scientific method in a communication course based on assessing their selection and summarization of papers on hypothesis-testing experiments, which was not explicitly required in the communication course that this study focused on. Beyond scientific method, developing abilities not only to conduct experiments but also to act based on evidence and ongoing reflection more completely encompasses what our students need to be able to do as professionals and citizens.

We hypothesized that explicitly engaging students in thinking about their thinking abilities within these frameworks would enhance their self-perception of scientific thinking, an important general ability for food scientists. The objectives of this study to improve scientific thinking skills were to assess student progress in such thinking skills through evaluating 1) periodic, structured self-reflection assignments and 2) student self-assessment surveys. This paper reports results of self-assessment data for five semesters (spring of 2012 through spring of 2014) during which we employed these approaches with different groups of students. These results confirm our hypothesis and qualitatively validate the use of a four-element construct of scientific thinking. This paper gives insight as to how other food science educators might incorporate educational activities that intentionally focus on scientific thinking into their own curricula.

Methods

Course and experimental design

Food Science and Human Nutrition (FSHN) 203 - Contemporary Issues in Food Science and Human Nutrition - is a one-credit sophomore seminar offered face-to-face one hour per week each semester. In this course, students learn to think scientifically and communicate about current issues in food science, culinary science, nutritional sciences and dietetics. They must consider the quality of claims made in the popular press about current issues, and evaluate the reliability of sources and ethical aspects of these issues. Course learning outcomes include: 1) Show awareness of the breadth of current research in food science, culinary science, nutrition, and dietetics; 2) Identify and discuss with faculty and with peers the significance of current issues in food science, nutrition, and dietetics; 3) Find and identify reputable and relevant sources of information about current issues in food science, nutrition, and dietetics; 4) Summarize technical information for peers in oral and written reports; 5) Relate professional codes of ethics to current issues in food science, nutrition, and dietetics; 6) Define, assess and plan self-development of professional abilities, focused on scientific thinking. The course culminates in students choosing a primary scientific journal paper (research article) and a review paper on one topic, presenting an oral summary of their chosen papers and preparing a written summary of the chosen papers as well. In each of the five semesters from spring 2012 through spring 2014, students in FSHN 203 were all FSHN majors (food science, culinary food science, nutritional sciences, dietetics); enrollments each semester were 27 (spring 2012, 2013, fall 2013), 24 (fall 2012), and 28 (spring 2014). Students completed quantitative and qualitative self-assessments of their scientific thinking at the beginning and end of the course. They also wrote a series of three scientific thinking reflections at weeks 1, 8 and 15 of the 16 week-long semester. In their end-of-semester reflection, students responded to this assignment: "Summarize your efforts this semester in working on your scientific thinking. Reflect about what and how you learned about scientific thinking in doing your final project for FSHN 203. Revisit the scientific thinking self-assessments provided in the Scientific Thinking Reflections folder in Blackboard; use these to guide your thinking. Give specific examples of situations in which you have practiced scientific thinking, and situations in which you might further improve your scientific thinking. How will you use scientific thinking in your profession? How will you continue to work on scientific thinking? How did your plans to work on scientific thinking progress; what will you emphasize for a next step and why?"

During spring semester 2013, we added assignments to engage students directly in assessing the quality of statements they made when asked to summarize one other student's presentation of a scientific paper (see Supplemental Materials, "Making Meaning" and "Summarizing Others' Final Presentations" worksheets). In fall 2013 and spring 2014, we introduced students to a "question the author" framework, loosely based on the work of (Beck and McKeown 1996) to focus more on developing their abilities to ask questions. We conceived this as a general framework to apply to their academic work and to the preparation of their scientific paper presentations. We had them use this framework to summarize one other student's oral presentation in spring 2014 (see Supplemental Materials, "Question the Author").

The Iowa State University Institutional Review Board determined that this research was exempt from review. We collected all student self-assessment results anonymously and we deleted potentially identifying comments from example reflections (Table 4).

Scientific thinking self-assessment instruments

A primary goal of the course was to help students accurately summarize reliable scientific literature, but prior experience indicated that students struggled with this. We developed self-assessment instruments to deepen student engagement in the thinking needed for their scientific paper summaries. We collected their pre- and post-course self-assessment responses to two versions of a thinking-like-a-scientist construct instrument. We measured their responses using 1) Likert scales (Tables 1, 2) and 2) word counts.

The first instrument we developed used a thinking-like-a-scientist construct of six elements/items directly derived from Williams and others (2004), using a six-point Likert scale from 1 = "strongly disagree” to 6 = “strongly agree” (see Supplemental Materials). We provided space for students to write reasons for their self-ratings. We used this instrument in spring 2012, fall 2012 and spring 2013. In addition to quantitative comparison of pre- and post- course scores, we also compared word counts of the narratives students provided for their self-ratings on pre- and post-course items for spring 2013. After our team developed a four-element thinking-like-a-scientist construct, in fall 2013 and spring 2014, a four-element self-assessment was used that included a five-point Likert scale (1= never to 5=always) and space to give reasons for self-ratings (see Supplemental Materials). We also analyzed word counts for students’ reasons for self-ratings for those two semesters.

A cross-disciplinary team of four faculty members from the fields of educational leadership, forestry, horticulture and nutrition, and a graduate research assistant in educational leadership developed the four-element construct of thinking-like-a-scientist. The team had a goal of creating a simple self-assessment instrument readily understood by any student. This self-assessment also allowed us to assess student progress in developing their abilities to think like scientists before and after they were engaged in learning activities related to this construct. The team reviewed literature about scientific thinking and related concepts, which included thinking-like-a-scientist (Williams and others 2004), scientific thinking (Gauch 2003), critical thinking (Brookfield 1987), and problem solving (Reed 2000). The team then compared these constructs to identify common elements, expressed as a simple acronym: REDI (Recognize, Explain, Do, Interpret). The team wrote, edited and reviewed this four-element self-assessment (see Supplemental Materials).

Other scientific thinking assessments analyzed

In fall 2013, we evaluated student responses to a scientific thinking scenario as an additional assessment instrument. This was presented to them at the beginning and end of the semester: “You are a Peace Corps worker in Kamuli District, Uganda, given the goal of helping a community improve the school lunch, currently a white corn porridge providing ~20% of the children's daily energy and protein requirements. Each family provides their children's share of the corn meal for the porridge but not all families can afford to. Outline how you would approach solving this problem." We chose an unfamiliar scenario on a topic not directly addressed during the course. The scenario also related to their fields of study because a food scientist may be involved in creating the food, a dietitian may evaluate a diet and a nutrition scientist may determine impact on the community.

Increased ability to think like a scientist seemingly requires increased cognitive complexity, so word count may also reflect gains in this ability. Linguistic Inquiry and Word Count software (LIWC 2015; Pennebaker Conglomerates Inc., Austin, TX) , a well-known tool for textual analysis, was used here to assess word count and relative numbers of words expressed that were associated with specific cognitive processes (insight, causation, discrepancy, tentativeness, certainty and differentiation). We compared these items for students' responses at the beginning and end of the semester. We think that the use of words in these categories correspond with aspects of scientific thinking. For example, a student expressing insight is indicating an ability to observe. Someone expressing causation-related words may be attempting to explain an observation. Words describing discernment of differences or tentativeness suggest that self-reflective and interpretive thinking is occurring. We also noted examples in their scenario responses that corresponded with one or more elements of the thinking-like-a-scientist construct that they had worked with.

As another assessment of student learning of scientific thinking, in each of five semesters of FSHN 203 (spring 2012, fall 2012, spring 2013, fall 2013, spring 2014), we analyzed students' end-of-semester scientific thinking reflections for the presence of elements of the thinking-like-a-scientist construct. One observer (Hendrich) recorded how many reflections contained these phrases or their synonyms in appropriate context: asked questions, defined problems scientifically, looked for or explained evidence, decided or made plans based on evidence, considered implications of decisions or plans, and revised/reflected/interpreted.

Statistical analysis

We compared Likert-scale scores on the thinking-like-a-scientist self-assessments completed at the beginning and at the end of each of the five semesters, as well as word counts of students' evidence for their ratings within these self-assessments by Student's t-tests (Denenberg 1976). We used paired Student's t-tests (Denenberg 1976) to compare LIWC data for students' written responses to a scientific thinking scenario at the beginning and end of fall 2013. We considered differences significant at $p < 0.05$.

Results and Discussion

Pre and post survey 1. Comparing post- with pre- surveys using a six-element scientific thinking self-assessment (Table 1), in spring 2012, students noted significantly stronger agreement with the statement "I continually revise and reflect." In fall 2012, students reported that they more strongly agreed with the statement "I define problems scientifically" but their level of agreement with the statement "I ask questions" declined significantly. In the 3rd semester of this effort to bring scientific thinking explicitly into this course (spring 2013), students reported significantly more agreement with the statement "I seek evidence". Additional assignments ("Making Meaning" and "Summarizing Others' Final Presentations", see Methods and Supplemental Materials) might have influenced their emphasis on this aspect of the thinking-like-a-scientist construct. Students generally at least somewhat agreed or agreed with all of the statements regarding their ability to think like scientists, corresponding with a score of four or five on the six-point Likert scale. In the semester in which students' self-assessment of their questioning ability declined from beginning to end of semester, they began with a mean score indicating that they agreed with the statement "I ask questions." It may be that they became more thoughtful and realistic about their questioning as the semester concluded.

<u>Pre and post survey 2.</u> From the four-element REDI scientific thinking self-assessment done in fall 2013 and spring 2014, in both semesters students significantly increased their assessment of how frequently they developed "plans based on evidence and reasoning to address situations or problems", when pre- and post-assessments were compared (Table 2). In fall 2013, they also more frequently noted that they interpreted how their plans worked on their post- assessment compared with the pre- assessment. In spring 2014, students tended to rate themselves on the post-assessment as more frequently asking questions than on the pre- assessment ($p < 0.10$). In spring 2014, the use of a "Question the author" framework (see Methods and Supplemental Materials) seemed to raise their awareness of questioning to some extent.

Across the two surveys, the second format may be somewhat more robust, with a greater proportion of survey questions showing significant pre- to post-semester changes indicating greater sense of self-efficacy in thinking-like-a-scientist, consistently in the area of developing plans based on evidence (Table 2). In the first version of the survey, making decisions based on evidence did not emerge as an element of thinking that students thought they had developed (Table 1). This difference in the students' response to the surveys illustrates the challenge of assessing student thinking. Gains in self-reflection may result in diminished positive self-rating or in nuances of development not readily reflected in a five- or six-point scale. We employed additional methods to capture our picture of student learning more fully.

Word counts. Word-count analysis of students' evidence for their self-assessment ratings of thinking like a scientist in spring 2013 showed significant increases ($p < 0.05$) in the areas of defining problems scientifically (pre 20 ± 11, post 25 ± 11; means ± standard deviations), and making decisions based on evidence (pre 20 ± 11, post 26 ± 12). Word count showed a trend to increase ($p < 0.08$) for seeking evidence (pre 20 ± 9, post 25 ± 11). In Fall 2013, using a four-element self-assessment, word counts in the area of gathering information and trying to explain situations/problems increased from pre- to post-course assessment (22 ± 11 vs. 30 ± 15, $p < 0.05$). In spring 2014, word count trended toward increase ($p < 0.08$) for the aspect of asking questions (pre, 25 ± 12, post, 31 ± 12). From pre- to post- assessment, word counts increased (but not significantly) for student explanations of their self-ratings for all elements, suggesting an increased familiarity with the constructs of scientific thinking used in this course. We may infer from the increased word counts that students were better at providing evidence for their claimed self-ratings in these areas, also indicating that the course enhanced their abilities to think scientifically. We explicitly emphasized the elements of "seeking evidence" and "gathering information…" (six-element and four-element assessment instruments, respectively) in the course. We required students to fnd scientific papers on a topic of their choice. This emphasis influenced self-assessment word count consistently. The word-count metric was an additional source of supporting evidence that students were effectively engaged in scientific thinking.

Total word counts may indicate gains in cognitive complexity, according to a review of applications of LIWC, a common approach to computerized textual analysis (Tausczik and Pennebaker 2010). In another example, analysis of medical student reflections showed that increased total word count was associated with higher reflection scores that indicated greater depth of reflection (Ottenberg and others 2016). Our LIWC analysis of student responses to a scientific thinking scenario in fall 2013 showed significantly increased total word count from beginning to end of semester, 40 ± 14 vs. 63 ± 21 words (means ± standard deviations; $p = 0.00003$). Students showed no beginning to end-of-semester differences in overall use of cognitive processing words, in words related to causation, discrepancies, tentativeness or certainty, but used relatively more words indicating greater insight at the end of the semester than at the beginning (2 ± 3 vs 0.8 ± 1.4, p < 0.0.038). They used relatively fewer differentiation words at the end of the semester than at the beginning in their scenario responses (4.4 ± 2.1 vs. 6.3 ± 3.6; $p < 0.026$). Overall word count increases in student scenario responses suggests a gain in thinking abilities. The greater use of words associated with insight also suggests such gains, but one might also expect greater rather than less use of differentiation words to accompany gains in scientific thinking. In a critical thinking course, LIWC analysis of students' thinking about a topic unrelated to course content showed a significant increase in students' use of words connoting certainty and decrease in words connoting tentativeness, suggesting to the author gains in students' clarity of thinking (Carroll 2007). While analogous thought processes may be occurring in students thinking like scientists and in students thinking critically, we did not see concordance between our study and Carroll's in longitudinal changes in student thinking according to LIWC cognitive word categories. Nevertheless, LIWC analysis indicated changes in students' word use in both course contexts, suggesting that this software might be useful in assessing gains in students' thinking abilities.

Both the six- and four-element scientific thinking self-assessment instruments may be useful tools for engaging students in thinking about scientific thinking. But it is of interest that student reflections, whether students had performed self-assessment with either instrument (see Supplemental Materials), more frequently included reference to the components mapping onto the four-element scientific thinking self-assessment. This supports the intuitive validity of the four-element REDI scientific thinking construct. Perhaps assignments directed at helping the students to develop a specific aspect of this construct, especially reiterative assignments, might facilitate the students' self-perception of gains in these abilities. The course has consistently offered students multiple opportunities to ask questions, with time for their questions after each student's oral presentation of a scientific paper (> 20 such presentations each semester), but question time is limited. Each semester, students were also guided in the course syllabus and in limited practice during class time in framing questions using Bloom's taxonomy (Bloom 1956): questions of clarification, translation, application, analysis, synthesis or evaluation. In the context of a one-credit course, opportunities to further enhance accountability for learning are somewhat limited. More formal accountability for asking questions, such as being required to write down a question on each presentation evaluation form and naming the taxonomic level of the question (with quality of assignment being assessed according to their successful completion of this task) might further improve student achievement of this aspect of scientific thinking.

Scenario results. The use of a scientific thinking scenario (See Methods) as an additional assessment of student progress in the quality of their thinking showed an increase from 54 ± 19 to 72 ± 24 words (mean ± standard deviation; $p < 0.05$). This suggests that students were able to think somewhat more specifically about the scenario problem at the end of the course than at the beginning. The nature of the scenario chosen as a more direct assessment of scientific thinking may be important to investigate further. It may be that a problem scenario that is more likely to be part of their everyday life might further facilitate students' use of scientific thinking, but it is also possible that everyday situations that they had not thought of as being amenable to scientific thinking might yield even more disparity in their ability to respond with scientific thinking. We intend to work more on helping students see the need for and gain effective practice in transferability of thinking like a scientist.

Analysis of scientific thinking reflections. Qualitative analysis of students' scientific thinking reflections revealed that nearly all students were able to name, describe, and provide evidence for their practice of at least one element of the scientific thinking construct that they used in the course (Table 3). Although mean word counts for these reflections did not differ significantly among semesters, (Table 3) there was a trend in later semesters toward a greater percentage of students noting in their reflections that they asked questions. In those semesters, we incorporated additional in-class activities based on asking questions (see Supplemental Materials for activities on Making Meaning, summarizing and questioning). In their reflections, most students provided examples of more than one element within the scientific thinking construct that they worked with. In many cases, students applied their scientific thinking to other courses and to their life experiences. We provided pertinent examples (Table 4). Providing guided self-reflective experiences is a powerful tool for students' intellectual development. In addition to guiding questions, students were given suggestions for the length of writing (250 words), which they exceeded on average (Table 3). Student saw the opportunity to self-reflect positively as they elaborated specific examples as evidence of their self-perceptions (Table 4). They often provided substantiation for their strengths as well as their areas of challenge in scientific thinking.

Conclusions

Introducing students to simple constructs of scientific thinking and providing practice in the elements of such constructs may enhance student self-perception and depth of self-reflection about such thinking. Seeing scientific thinking as useful and seeing oneself as capable of this kind of thinking will provide a stronger foundation for student achievement in food science and human nutrition. As one student expressed, "Being a Food Science Major, scientific thinking will be a big part in my major. Dealing directly with experiments or even addressing problems that arise in the manufacturing companies. This step by step and open thinking will allow me to succeed in my career field."

Table 1. Thinking-Like-a-Scientist self-assessment version 1 pre- and post-course survey scores increased after a one-semester course that engaged students in a scientific thinking process.

Survey item	Spring 2012-pre (N = 21)	Spring 2012-post (N = 21)	Fall 2012-pre (N = 22)	Fall 2012-post (N = 22)	Spring 2013-pre (N = 21)	Spring 2013-post (N = 21)
I ask questions.	4.2 ± 1.2	**4.4 ± 1.3**	5.0 ± 0.8	**4.5 ± 0.9**[b]	4.6 ± 0.8	**4.8 ± 0.9**
I define problems scientifically.	4.0 ± 1.0	**4.3 ± 0.7**	4.2 ± 0.9	**4.8 ± 0.8**[a]	4.0 ± 1.1	**4.3 ± 0.7**
I seek evidence.	4.9 ± 0.7	**4.9 ± 0.9**	5.0 ± 0.7	**5.0 ± 0.8**	4.7 ± 0.6	**5.2 ± 0.7**[a]
I make decisions based on evidence.	5.0 ± 0.7	**4.9 ± 0.7**	4.7 ± 0.9	**5.0 ± 0.8**	4.9 ± 0.6	**5.0 ± 0.8**
I consider implications and applications of decisions.	4.5± 1.1	**4.6 ± 0.8**	4.9 ± 1.0	**5.0 ± 1.0**	4.5 ± 0.9	**4.7 ± 0.7**
I continually revise and reflect.	4.1 ± 1.0	**4.8 ± 0.6**[a]	4.5 ± 1.1	**4.7 ± 1.2**	4.7 ± 1.0	**4.5 ± 1.2**

[a]Denotes statistically significant increase from pre- to **post**-semester self-assessment, $p < 0.05$.
[b]Indicates statistically significant decrease from pre- to **post** assessment within semester. Each item was assessed on a six-point Likert scale from 1= strongly disagree to 6 = strongly agree. Data are means ± standard deviations, N = total self-assessments submitted each semester.

Table 2. Changes in pre- post-course self-ratings using a thinking-like-a-scientist self-assessment (version 2).

Survey item	Fall 2013-pre (N = 22)	Fall 2013-post (N = 22)	Spring 2014-pre (N = 22)	Spring 2014-post (N = 22)
I ask questions about what is going on around me.	3.5 ± 0.8	**3.7 ± 0.7**	3.6 ± 0.8	**3.9 ± 0.5**
I gather information and try to explain situations or problems around me.	3.5 ± 0.9	**3.8 ± 0.8**	3.7 ± 0.9	**3.9 ± 0.7**
I develop plans based on evidence and reasoning to address situations or problems.	4.0 ± 0.6	**4.3 ± 0.5**[a]	3.5 ± 1.1	**4.0 ± 0.7**[a]
I interpret how my plan worked.	3.4 ± 1.0	**4.1 ± 0.8**[a]	3.5 ± 1.1	**4.0 ± 0.8**

[a]Denotes statistically significant increase from pre- to **post**-semester self-assessment, $p < 0.05$.
Each item was assessed on a five point Likert scale from 1= never to 5 = always. Data are means ± standard deviations N = total self-assessments submitted each semester.

Table 3. Numbers and percentages of end-of-semester student reflections[a] specifically referring to elements of scientific thinking in a course on current issues in food science and human nutrition.

	Spring 2012	Fall 2012	Spring 2013	Fall 2013	Spring 2014

Number of student reflections:	20	20	23	24	23
Mean number of words/reflection ± standard deviation:	383 ± 157	337 ± 148	410 ± 231	460 ± 170	411 ± 122
Element of scientific thinking:					
Asking questions	9 (45%)	9 (45%)	13 (57%)	15 (63%)	14 (65%)
Defining problems scientifically	1 (5%)	0 (0%)	2 (9%)	2 (8%)	1 (4%)
Seeking evidence/explaining	10 (50%)	8 (40%)	6 (26%)	9 (38%)	11 (48%)
Deciding/planning based on evidence	7 (35%)	2 (10%)	10 (43%)	13 (54%)	7 (30%)
Considering implications of plans/decisions	2 (10%)	3 (15%)	1 (4%)	1 (4%)	2 (9%)
Revising/reflecting/interpreting	6 (30%)	7 (35%)	9 (39%)	7 (29%)	9 (43%)

[a]See Methods for assignment instructions. Numbers of reflections analyzed were the totals submitted each semester.

Table 4. Examples of end-of-semester student reflections specifically referring to at least one element of scientific thinking in a course on current issues in food science and human nutrition.

Element of scientific thinking	Example
Asking questions	“The final project in FSHN 203 helped me to start asking questions. While listening to presentations, I made it my goal to think of a question to write down... Some of the questions I asked were better than others, but I was able to think of something for almost everyone. I was just trying to get in the habit of listening in such a way that I could come up with any sort of question. I think as I continue to work on this, my questions will be better and reflect deeper thinking.”
Defining problems scientifically	“I realized that my step by step process I used to solve everyday issues or problems was in fact a form of scientific thinking. As the semester progressed I began to become more aware and used the thinking more often. For example I am taking…Organic Chemistry…and I was having a hard time grasping all the different…circumstances that were involved in the process of different molecules. Then I realized I could set up a step by step process showing everything that occurred for the various molecules…This allowed me to …have a better grasp on the material.”
Seeking evidence/ Explaining	“Sometimes, I would believe it without looking any further in to it. There are so many different claims out there that it is hard for someone who is not educated in the nutrition field to differentiate between what is reliable and what isn't…on my final project, I learned that more than one extensive study is needed to prove that eating any type of food will change your risks for certain diseases…much more research from other studies was needed to support the claim.”
Deciding/ planning based on evidence	“For the final presentation…I used the rubric from class to judge the validity of the research articles I presented. I also use that rubric and other tools for other classes…I am writing a paper about a controversial issue in nutrition. I used the rubric to determine the strongest sources of information for the paper. I also used the “making

	meaning" rubric to help interpret research articles and explain them in my own words for the assignment."
Considering implications of plans/decisions	"When I enter the career world, I think this strategy will be so important when it comes to assessing diets and how health plans are working for others. It will be important to ask what they need help with, make a plan, and then assess how it is affecting them. It will be beneficial to have these…steps in the back of my mind, so I can meet the needs of my clients."
Revising/reflecting/interpreting	"The efforts that were most successful in developing my scientific thinking were when I reflected on questions that I couldn't figure out, so I had to resort to other methods using scientific thinking to be able to come up with a solution. I will practice scientific thinking in my profession, by coming up with new and creative ways to help my clients eat right and exercise when they have struggled with many other techniques at trying to do so."

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