2019

Using Interactive Nutrition Modules to Increase Critical Thinking Skills in College Courses

Jade McNamara

Sara Sweetman
University of Rhode Island, sara_sweetman@uri.edu

Priscilla Connors

Ingrid E. Lofgren
University of Rhode Island, ingrid_lofgren@uri.edu

Geoffrey Greene
University of Rhode Island, ggreene@uri.edu

This is a pre-publication author manuscript of the final, published article.

Citation/Publisher Attribution

McNamara, J., Sweetman, S., Connors, P., Lofgren, I., & Greene, G. (2019). Using Interactive Nutrition Modules to Increase Critical Thinking Skills in College Courses. *Journal of Nutrition Education and Behavior, 52*(4), 343-350. doi: 10.1016/j.jneb.2019.06.007
Available at: https://doi.org/10.1016/j.jneb.2019.06.007

Journal of Nutrition Education and Behavior

USING INTERACTIVE NUTRITION MODULES TO INCREASE CRITICAL THINKING SKILLS IN COLLEGE COURSES

--Manuscript Draft--

Manuscript Number:	JNEB-D-18-00761R3
Full Title:	USING INTERACTIVE NUTRITION MODULES TO INCREASE CRITICAL THINKING SKILLS IN COLLEGE COURSES
Article Type:	Research Article
Section/Category:	Special Issue: Scholarship of Learning
Keywords:	Critical Thinking; Decision Making; STEM Education; Problem-Based Learning
Corresponding Author:	Jade McNamara, Ph.D. University of Maine Orono, Maine UNITED STATES
First Author:	Jade McNamara, Ph.D., RDN
Order of Authors:	Jade McNamara, Ph.D., RDN
	Sara Sweetman, Ph.D.
	Priscilla Connors, Ph.D., RDN
	Ingrid Lofgren, Ph.D., RDN
	Geoffrey W Greene, Ph.D., RDN
Abstract:	Objective: To understand how the addition of an evidence-based framework to an online nutrition module influences college students' critical thinking decision making (CT-DM). Design: Students were individually randomized into an intervention group or a control group. The nutrition modules focused on two topics related to different types of eating behavior. Students completed a CT-DM activity to generate a score. Participants: College students, between 18-24 years old, recruited from introductory nutrition and agriculture science courses at two universities. Intervention: Intervention and control received two nutrition modules. The intervention added a CT-DM framework that framed the topic as a problem, incorporated activities, and provided scaffolding. Main Outcome Measure(s): CT-DM was scored using a validated rubric to assess the use of critical thinking skills when making a food-related decision. Green eating and critical thinking disposition were measured. Analysis: Hierarchical linear regression and t-tests were used to assess outcomes. Results: 431 students participated (intervention=203; control=228). After controlling for university, the intervention group scored significantly higher on CT-DM (18.1±7.6) compared to the control (15.4±8.4); F (3,428) =14.58, p<.001. Conclusions and Implications: The results show that an evidence-based framework using nutrition topics encourages CT-DM skills. Future nutrition higher-education interventions should use frameworks to enhance student learning.

Cover letter:

This manuscript is being submitted as a *Research Article.* The manuscript was written specifically for the Scholarship of Learning special issue. This research focuses on how evidence-based instructional practices can be used to encourage critical decision making skills in introductory nutrition and agriculture courses. The manuscript has not been and will not be submitted elsewhere for publication. The evidence-based instructional practices that were operationalized and used in this research were described and evaluated in a separate manuscript that is currently under review, however, no overlapping outcomes between the manuscripts were used. All authors have reviewed and approved the complete manuscript including tables and the figure. The complete page count is 18 pages and 5,212 words.

Potential reviewers:

Sarah Martin Gould, PhD, RDN
Associate Professor

University of Northern Colorado, School of Human Sciences, Nutrition and Dietetics Program, Greeley, CO

Email: susan.gould@unco.edu
Phone: 970-351-1705

Dustin Perry, PhD
Assistant Professor

Montana State University
Division of Agricultural Education College of Agriculture Montana State University (MSU), Bozeman, MT

E-mail: Dustin.Perry@Montana.edu
Phone: 406-994-5773

TITLE PAGE

USING INTERACTIVE NUTRITION MODULES TO INCREASE CRITICAL THINKING SKILLS IN COLLEGE COURSES

Research Article

Jade McNamara, PhD.[1], Sara Sweetman, Ph.D.[2], Priscilla Connors, Ph.D., RDN[3], Ingrid Lofgren, Ph.D., RDN[4], Geoffrey Greene, Ph.D., RDN[4]

1. School of Food and Agriculture, University of Maine, Orono, ME
2. School of Education, University of Rhode Island, Kingston, RI
3. College of Merchandizing, Hospitality and Tourism, University of Northern Texas, Denton, TX
4. Department of Nutrition and Food Science, University of Rhode Island, Kingston, RI

Corresponding Author:

Jade McNamara
7 Portage Road
University of Maine
Orono, ME 04469
Phone Number: 207-581-4895
E-mail: jade.mcnamara@maine.edu

This research was completed while Jade McNamara was at the University of Rhode Island

41 Lower College Rd
University of Rhode Island
Kingston, RI 02881

Acknowledgments

This research was conducted as part of Jade McNamara's dissertation research. The development of the online applications was produced by the University of Rhode Island's Media and Technology Department. Thank you to the Undergraduate Research Assistants who scored the critical thinking decision making responses.

Abstract

Objective: To understand how the addition of an evidence-based framework to an online nutrition module influences college students' critical thinking decision making (CT-DM).

Design: Students were individually randomized into an intervention group or a control group. The nutrition modules focused on two topics related to different types of eating behavior. Students completed a CT-DM activity to generate a score.

Participants: College students, between 18-24 years old, recruited from introductory nutrition and agriculture science courses at two universities.

Intervention: Intervention and control received two nutrition modules. The intervention added a CT-DM framework that framed the topic as a problem, incorporated activities, and provided scaffolding.

Main Outcome Measure(s): CT-DM was scored using a validated rubric to assess the use of critical thinking skills when making a food-related decision. Green eating and critical thinking disposition were measured.

Analysis: Hierarchical linear regression and t-tests were used to assess outcomes.

Results: 431 students participated (intervention=203; control=228). After controlling for university, the intervention group scored significantly higher on CT-DM (18.1±7.6) compared to the control (15.4±8.4); $F(3,428) = 14.58$, $p < .001$.

Conclusions and Implications: The results show that an evidence-based framework using nutrition topics encourages CT-DM skills. Future nutrition higher-education interventions should use frameworks to enhance student learning.

(Word Count: 200)

Key Words: Critical Thinking, Decision Making, STEM Education, Problem-Based Learning

USING INTERACTIVE NUTRITION MODULES TO INCREASE CRITICAL THINKING SKILLS IN COLLEGE COURSES

INTRODUCTION

Twenty first century skills that include critical thinking, have been identified by employers of college graduates as more important than academic success in making hiring decisions.[1-3] This is, in part, related to the increasing pace of scientific discovery and advances in technology that requires critical thinking skills. There is evidence that individuals with high level critical thinking skills make better decisions, such as taking less unnecessary risks, than those with less developed critical thinking skills.[1,4] However, teaching critical thinking skills in introductory college courses is challenging, particularly in science, technology, engineering and math (STEM) disciplines such as nutrition and animal sciences where there is a high focus on memorizing critical information.[5,6] There also have been few research studies focusing on the science of teaching and learning addressing critical thinking within STEM courses.

Critical thinking skills include the ability to apply standards, seek out information, problem solve, transform knowledge, predict consequences of decisions, be creative, practice logical reasoning, and evaluate evidence when faced with a problem or question.[7-9] Because critical thinking is such a broad construct and includes so many skills, it is difficult to measure for educational outcomes.[10] Narrowing the construct of critical thinking to critical thinking decision making (CT-DM), defined by having skills in problem solving, logical reasoning, and evaluating evidence when making decisions[9], allows for realistic measurement methods and facilitates curriculum development.

A learner-centered curriculum fosters CT-DM by allowing students to connect thoughts and ideas through reflection of what they already know, investigation of new knowledge, and explicit skill development.[11, 12] Learner-centered curricula can be operationalized through the theory of social constructivism using problem-based learning (PBL) activities.[13, 14] Social constructivism theory postulates that students learn by connecting concepts to previous knowledge and experiences[15, 16], while PBL provides students with opportunities to assess complex problems using a variety of resources, and develop their own strategies for addressing these problems.[17, 18] However, incorporating PBL into introductory STEM classes is difficult due to discipline and accreditation demands for course content. One solution to overcome these time constraints has been to utilize out-of-class, online PBL activities to enhance skill development and motivate students to engage in learning activities. Additionally, students have expressed frustration with PBL activities, particularly in introductory courses, because of a lack of framework to successfully complete the tasks,[19] which underscores the importance of intentionally designing activities and using topics that motivate students to engage in learning.

In addition to pedagogical strategies, personal factors such as attitude towards critical thinking or interest in the PBL topic may affect student engagement with the curriculum.[20, 21] Some students are naturally more open to using critical thinking skills, which has been assessed in previous research by the critical thinking disposition scale (CTD)[22], which may influence the outcome of a CT-DM intervention. Also, researchers have shown that personal interest in a topic motivates students to participate, express their point of view and engage in a learning activity.[23] For example, nutrition and food choice topics are ideal for motivating students to engage in learning because the majority can connect with those scenarios as they are making eating and food choice decisions daily. One way of assessing personal interest in a topic is by measuring self-reported behaviors pertaining to the topic. Both variables, CTD and personal interest in a topic, need to be measured to evaluate the role they play in explaining CT-DM.

Thus, the primary objective was to determine if the addition of a contextual framework, defined in this study as the critical thinking decision making framework (CTDM-F), to a two-module, online PBL curriculum influences college students' CT-DM skills. The second objective was to explore the relationship between the mediating factors of CTD and personal interest in a topic on CT-DM skills. The primary hypothesis was that undergraduate students exposed to the CTDM-F would have a significantly higher CT-DM score when compared to the students in the control group and that CTD and interest in the topic would be mediators of CT-DM score.

METHODS

Research Design

This study was a randomized controlled trial, where students from two geographically diverse universities (University of Rhode Island and University of North Texas) were recruited from introductory level nutrition and animal science courses, and individually randomized into to a CTDM-F group or a control group. The study was approved at both universities by their respective Institutional Review Boards. Students were provided with a link to access the online consent to participate in the research study and sign-up for the modules. Students were then randomized into either the CTDM-F group or control group by the computer. Students were then directed to an online pretest, assessing key mediating variables such as inclination to use critical thinking (measured by CTD), prior interest in the topic of sustainable eating (measured by green eating behavior (GE)) and demographic data. They were then immediately directed to the first module: pros and cons of animal protein vs. non-animal protein food choices. One week later, they were notified that the second module was available: pros and cons of organic food vs. non-organic food choices. The post-test immediately followed module 2, which was similar to the pretest.

The topics for the modules, animal vs. plant-based sources of protein and organic vs. non-organic food, were chosen because both topics can be argued from multiple perspectives and relate to authentic scenarios that college students may face when making food purchasing or eating decisions. As higher education institutions move towards providing greater education on sustainable practices and sustainably produced food choices[24], college students will be faced with these decision making scenarios. Previous research also supports that college students are interested in topics related to environmentally conscious eating and find these topics motivating for learning.[25]

CT-DM Module and Control Module

Both modules were easily accessible to students from various platforms via internet connections and took about 15 minutes to complete. Module 1 began with an interactive "quiz" to determine what type of learner the student was, a video discussing the importance of critical thinking, and two videos addressing both sides of the specific topic area (animal protein vs. non-animal protein foods). After watching the topic video, the student was asked to make a decision about which side they agreed with and then were prompted to write a brief response explaining why they made that decision. Module 2 had the same format as module 1 and then was followed by the post-test.

Critical Thinking Decision-Making Framework

The CTDM-F was designed using the social constructivism model with the aim to bring about a conceptual change in student thinking by having the student construct their own conclusions when presented with information.[15, 16] Scaffolding, or structuring the learning process to help the learner more towards independence, was also a key component in the CTDM-F.[15, 16] The three specific strategies to operationalize an online delivery of social constructivism with an emphasis on scaffolding, were as follows: 1) topic was introduced as an authentic problem[26], 2) an input scaffold in the form of a t-chart was provided to help organize information from the two sources with alternative views [27], and 3) an output scaffold was provided to help frame the argument separate from decision making[28], in the form of a "mind-map". The "mind-map" was an activity where students structured their response with their decision and reasoning using a drag-and-drop activity. For module 1, the CTDM-F provided more scaffolding for the decision-making activity by using a closed exercise format with fill-in-the-blanks structured responses. For module 2, the scaffolding in the decision-making activity was removed by providing only a blank text box for recording the decision-making response.

Control Module. The control group was exposed to the same videos but did not have the topic introduced as a problem, did not receive the input scaffold and did not have an output scaffold. They were provided with a blank decision-making text box in both modules. The differences in the layout of module 1 and module 2 between groups is described in Table 1.

[TABLE 1]

Measurements

Primary Outcome: Critical Thinking Decision-Making Score. To calculate the CT-DM score, a previously developed and tested rubric[29] was used to score the decision-making activity at the end of module 2, when both groups received the text box. Scores ranged from 0-30, evaluating the extent of CT-DM, with 0 representing a non-response/failed to provide a text response addressing the task, and 30 indicating a text response that addressed the three following constructs: 1) ability to make a decision (0/10 points), 2) evidence to support the decision (0-15 points), and 3) ability to see the other side's point of view (0/5 points). The responses were scored using a computer-assisted scoring system that guided trained researchers through the response criteria generating a total score. The passing rate for training was set at an interrater reliability (IRR) score of ≥.80, which has been used in previous research as an acceptable agreement score.[30] All responses were duplicate scored by research assistants (n=4) who participated in training and were evaluated for reliability based on matching rate. Scores that did not match (18%) were then scored by a senior researcher to determine a final score.

Critical Thinking Disposition. Disposition to use critical thinking operationalized as CTD was measured using a 5-item subscale from the Motivated Strategies for Learning Questionnaire (MSLQ).[22] The subscale was designed and validated to measure college students' thinking strategies to apply knowledge and critically evaluate situations and found to have good internal reliability with a Cronbach's alpha (α) value of .72.[31] The composite score is an indicator of students' inclination to use CT during a decision-making process.[22] The five items were measured using a 5-point Likert scale, ranging from (1) strongly disagree (5) strongly agree.

Green Eating Behavior. Prior interest in the topic, operationalized as GE behavior, was measured using a validated 7-item survey (α = .81), which assessed the frequency of choosing sustainably produced food.[24] The items included behaviors related to purchasing foods locally grown, shopping at farmer's markets, buying organic, and purchasing free-range animal proteins. Items were measured on a 5-point Likert scale ranging from (1) barely ever to never to (5) almost always, a higher score indicating a greater frequency of choosing sustainably produced foods.

Data Analysis

Data were analyzed using SPSS 24 (IBM, Armonk, NY, 2016). Descriptive variables were analyzed for normal distribution using values of -2 to +2 for skewness and kurtosis.[32] Demographic variables were analyzed using means (± standard deviation) and frequency (%). Independent t-tests were used to analyze baseline differences between the CTDM-F and the control groups, and between universities. Analysis of covariance (ANCOVA) was conducted at baseline to control for significant differences between groups. A Pearson's Chi-square test of independence analysis was used to analyze categorical variables. To assess differences in CT-DM score between groups, a two-stage hierarchical multiple regression was performed with CT-DM score as the dependent variable. University was entered at stage one of the regression to control for differences at baseline. Group (control vs CTDM-F) was entered at stage two to assess differences between groups on CT-DM score after controlling for university. ANCOVA was also used to assess differences in scores and components of the CDM score between groups. To evaluate change in CTD score and GE behavior from baseline to post-intervention, repeated measures ANCOVA was conducted. For all the analyses significance level was set at $p<0.05$. An exploratory structural equation model (SEM) using path analysis was also performed to explore the amount of variation that was accounted for in CT-DM score by group, CTD, and GE behavior. For the SEM outcomes, ideal macro-level fit indices parameters include: χ^2 $p >.05$, χ^2/df ratio < 4, CFI > .90, RMSEA < .08, and for χ^2 difference, a larger value equates to better fit.[32]

RESULTS

Sample

A total of 440 students randomly assigned to either the control (n=230) or the CTDM-F group (n=210). Participants were excluded if they did complete baseline demographic questions and if they did complete both module 1 and module 2 (n=9). Students' mean age was 19.4 (±1.4) years old and 73.8% were female. All descriptive variables were normally distributed. Reported major was grouped into three categories: 1) Arts and Humanities: social sciences, arts, and undecided (47.5%); 2) STEM: science, technology, engineering, agriculture, and math (22.2%); and 3) STEM-Health: nutrition, kinesiology, nursing, pre-med (30.3%) to examine differences.

Significant baseline differences between universities were found for all categorical and descriptive variables. Based on these findings, university was controlled for in the analyses using ANCOVA. Baseline comparisons between groups, after controlling for university, are shown in Table 2. At baseline, the control group initially had a significantly higher pre-CTD score ($p<.05$), but after controlling for university, the difference was no longer significant. No other differences between the CTDM-F group and control group were found.

[TABLE 2]

CT-DM Score

The hierarchical multiple regression revealed that at step 1, university contributed significantly to the regression model, F (2,428) = 19.11, $p< .001$ and accounted for 8.0% of the variation in CT-DM-score. Introducing the grouping variable (CTDM-F group vs. control group) explained an additional 3.0% of the variation in CT-DM score and the change in R^2 was significant, F (1,428) = 25.45, $p<.001$. The results show that after controlling for university, the grouping variable explained a significant proportion of the variation in CT-DM scores, demonstrating that the CTDM-F group had a significantly higher CT-DM score than the control group.

Group differences in CT-DM score components were assessed using ACOVA and are presented in Table 3. Results show a greater percentage of the intervention group made a decision and used significantly more evidence-based reasons to support their decision when compared to the control. However, there were no differences between groups in recognizing the other side's point of view.

After controlling for university using repeated measures ANCOVA, there were no between group differences in CTD or GE over time. However, there was a significant within-group change in CTD for both the CTDM-F group from a mean baseline value of 3.52 (±.6) to a post-intervention mean of 3.63 (±.6), $p<.01$ and the control group from a baseline mean of 3.54 (±.6) to a post-intervention mean of 3.69 (±.6), $p<.001$. There were no significant within group changes for GE behavior.

For the exploratory SEM path analysis, three model versions were hypothesized and tested using EQS software[33]: direct, predictive, and mediational models. Findings revealed that compared to a direct model with only a single predictor from group to CT-DM score, and a mediational model with CTD and GE behavior as mediators, a third prediction model with paths from three predictors (group, CTD, and GE behavior) fit best.

Macro-level fit indices showed that the χ^2, df, CFI, and RMSEA were all in a near-optimal range for the selected prediction model (Table 4). In contrast, fit indices for the direct effect and mediational pathway indicated that these models were not adequately describing the data. Standardized maximum likelihood parameter estimates for the prediction model path coefficients are shown in Figure 1, along with R^2 values. The results indicate that group and interest, (i.e., GE behavior) were significant predictors of CT-DM score, but CTD score was not a significant predictor of CT-DM score.

DISCUSSION

The purpose of this study was to evaluate the effectiveness of a CTDM-F to facilitate CT-DM skills in large introductory STEM classes. Findings showed that the CTDM-F, provided as an out-of-class activity, was successful at encouraging students to use more CT-DM skills when compared to the control group. Specifically, The CTDM-F group was better at making a decision and supporting that decision with a greater number of evidence-based reasons. These findings were similar to other interventions that were implemented in semester-long courses[34], highlighting that online modules with an appropriate framework to facilitate learning can be used as supplemental instruction to support higher order thinking skills. This study demonstrated the importance of incorporating an instructional framework to intentionally teach skills associated with CT-DM as well as encourage the significance of skill development for using critical thinking skills during a decision-making scenario.

The success of the online interactive modules in facilitating CT-DM can be attributed to grounding the curriculum within the social constructivism theory, using PBL, and scaffolding the learning to help students move towards independence in their CT-DM skills. The findings in this study are reinforced by Perry et al.[35], who implemented similar methods using PBL activities throughout a semester-long course in a large introductory class. Their findings showed that students increased their critical thinking skills from the beginning of the semester compared to the end when exposed to competing viewpoints of topics related to sustainability. Developing critical thinking skills is essential because both educators and employers have expressed the need for students to graduate from higher education with strong critical thinking skills.[36, 37] However, developing these skills require use of curricula that implement evidence-based instructional practices based on research in the science of teaching and learning.

Interestingly, while the experimental group made a decision more often and used more evidence to support their decision, the CTDM-F was not successful at having students recognize the differing perspective. One reason for this may be because a discussion activity was not included, which has shown to encourage recognition of other perspectives and to identify the other side's point of view.[38] Extending the framework by adding an additional module with more scaffolding and a discussion activity would help students move towards greater independence in their CT-DM response.

The current study found no significant differences between groups in change in attitudes toward critical thinking measured by CTD; both groups increased scores from baseline to post. The increase in the CTD scores over time can be explained by both groups being exposed to the same components of PBL instruction such as the critical thinking video, the competing narratives in both modules and the decision-making activity.[39, 40] Additionally, there were no changes in GE behavior from pre-test to post-test or between groups. This suggests that even though the modules provided pros and cons of different environmental eating positions, additional intervention components such as goal setting may be needed to lead to behavior change.[25]

The path analysis showed that the CTDM-F and GE behavior were significant, independent predictors of CT-DM score, while CTD was not. This provides additional support that the framework encouraged the use of CT-DM skills. The path analysis showed that a prediction model fit better than a mediation or null model. This indicates that interest, or frequency of GE behavior, is an important variable to consider when predicting CT-DM score, but it was not a meditating variable, so it did not strengthen or weaken the CT-DM score.

Researchers have found that when students express more interest in a topic, they have a greater motivation to engage in critical thinking activities during low stakes assessment (e.g., extra credit).[41, 42] Bruna et al.[21] found that when PBL was used to teach metabolism using nutrition and health articles, instead of a traditional lecture format, students reported more motivation to participate, engaged more in self-directed learning, and reported that the learning process encouraged them to use critical thinking skills. The authors contributed the positive outcomes of the study to the use of authentic education material where students were solving real-world problems. This supports why GE behavior was a significant predictor of CT-DM score. While GE may have led to a higher CT-DM score for those reporting higher GE behavior, it may have reduced CT-DM scores for those students who were not as involved in sustainable eating behavior. Nevertheless, the importance of interest in a topic was reinforced by the path analysis findings.

The path analysis also revealed that CTD score did not account for a significant amount of variation in CT-DM score. This is conflicting with other studies that have found that CTD is an indicator of critical thinking skills[43], however the main outcome for this study measured CT-DM skills rather than the larger construct of critical thinking, which is a possible explanation as to why CTD was not a significant predictor of the outcome. Furthermore, having a natural inclination to be a critical thinker does not equate to having strong critical thinking skills.[31] For example, students may have recognized the need to use critical thinking in their courses (i.e., measured by CTD score) but may not have progressed to the stage of implementing those strategies (i.e., measured by CT-DM score). Overall, the CT-DM framework intervention was not sufficient to cause a change in students' CTD when compared to the control.

The previous discussion brings forth a limitation. This study did not measure the broader construct of critical thinking, which limits the ability to completely understand how the CTDM-F impacted students' ability to think critically. Despite the limitation, this intervention used a rigorous study design and introduced a novel approach that facilitated CT-DM skills by using an online interactive framework that can be easily administered online or in a classroom setting and be manipulated to fit multiple topics within the STEM fields and beyond.

IMPLICATIONS FOR FUTURE RESEARCH AND PRACTICE

This research supports the importance of including evidence-based instructional practices such as social constructivism theory and PBL when developing curricula, along with using topics that students can relate to such as examining sustainable food system practices and making food choices. Through the science of teaching and learning educators have the opportunity to develop curricula that encourages students to consider and evaluate facts, which is imperative for STEM students to master as they begin their careers. As future professionals, this generation faces future problems that are unpredictable and while information is more abundant than ever, the use of the internet and technology requires information seekers to be critical of the facts they consider when making complex decisions.

To further enhance the science of teaching and learning, the CTDM-F should be tested and administered in classroom settings to examine how a framework can be used to develop critical thinking skills and help students make informed decisions. Future implications include understanding how the CTDM-F can work to overcome pre-existing biases or emotional reasoning during a decision making scenario, along with measuring the broader construct of critical thinking using validated measures.[10, 44] This would provide a more complete understanding of how critical thinking impacts students' decisions. As evident by this study, using a framework within two online interactive modules was found to be a facilitator of CT-DM and students were more likely to recognize and use facts when making a simulated decision about food choices.

REFERENCES

1. Butler HA. Halpern Critical Thinking Assessment Predicts Real- World Outcomes of Critical Thinking. *Applied Cognitive Psychology*. 2012;26(5):721-9.
2. Desai MS, Berger BD, Higgs R. Critical thinking skills for business school graduates as demanded by employers: a strategic perspective and recommendations. *Academy of Educational Leadership Journal*. 2016;20(1).
3. Dwyer CP, Hogan MJ, Stewart I. An integrated critical thinking framework for the 21st century. *Thinking Skills and Creativity*. 2014;12:43-52.
4. Franco A, Costa PS, Almeida LS. Do critical thinkers drink too much alcohol, forget to do class assignments, or cheat on exams? Using a critical thinking measure to predict college students' real-world outcomes. *Psychological Studies*. 2017:1-10.
5. Knight JK, Wood WB. Teaching more by lecturing less. *Cell Biol. Educ*. 2005;4(4):298-310.
6. Gasiewski JA, Eagan MK, Garcia GA, et al. From gatekeeping to engagement: A multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Research in higher education*. 2012;53(2):229-61.
7. Duron R, Limbach B, Waugh W. Critical thinking framework for any discipline. *International Journal of Teaching and Learning in Higher Education*. 2006;17(2):160-6.
8. Rudd R, Baker M, Hoover T. Undergraduate agriculture student learning styles and critical thinking abilities: Is there a relationship? *Journal of agricultural education*. 2000;41(3):2-12.
9. Scheffer BK, Rubenfeld MG. A consensus statement on critical thinking in nursing. *Journal of Nursing Education*. 2000;39(8):352-9.
10. Liu OL, Frankel L, Roohr KC. Assessing Critical Thinking in Higher Education: Current State and Directions for Next- Generation Assessment. *ETS Research Report Series*. 2014;2014(1):1-23.
11. Brown KL. From teacher-centered to learner-centered curriculum: Improving learning in diverse classrooms. *Education*. 2003;124(1):49.
12. Huba ME, Freed JE. Learner centered assessment on college campuses: Shifting the focus from teaching to learning. Boston, MA: Allyn and Bacon, 2000.
13. Hendry GD, Frommer M, Walker RA. Constructivism and problem- based learning. *Journal of further and higher education*. 1999;23(3):369-71.

14. Mughal F, Zafar A. Experiential learning from a constructivist perspective: Reconceptualizing the Kolbian cycle. *International Journal of Learning and Development*. 2011;1(2):27-37.
15. Taylor PC. Constructivism: value added. *International handbook of science education*. 1998;2:1111-23.
16. Vygotsky LS. Thought and Language: MIT Press, Massachusetts Institute of Technology and John Wiley and Sons, 1962.
17. Hannafin MJ, Hill JR, Land SM. Student-centered learning and interactive multimedia: Status, issues, and implication. *Contemporary Education*. 1997;68(2):94.
18. Yew EH, Karen G. Problem-based learning: an overview of its process and impact on learning. *Health Professions Education*. 2016;2(2):75-9.
19. Kim K, Sharma P, Land SM, et al. Effects of Active Learning on Enhancing Student Critical Thinking in an Undergraduate General Science Course. *Innovative Higher Education*. 2013;38(3):223-35.
20. Kek M, Yih Chyn A, Huijser H. The power of problem- based learning in developing critical thinking skills: preparing students for tomorrow's digital futures in today's classrooms. *Higher Education Research & Development*. 2011;30(3):329-41.
21. Bruna CE, Valenzuela NA, Bruna DV, et al. Learning Metabolism by Problem- Based Learning Through the Analysis of Health or Nutrition Articles from the Web in Biochemistry. *Journal of Food Science Education*. 2019;18(2):37-44.
22. Pintrich PR, Smith DAF, García T, et al. Reliability and predictive validity of the Motivated Strategies for Learning Questionnaire (MSLQ). *Educational and psychological measurement*. 1993;53(3):801-13.
23. Trosset C, Weisler S. Using longitudinal assessment data to improve retention and student experiences. *New Directions for Institutional Research*. 2010;2010(S2):79-88.
24. Weller KE, Greene GW, Redding CA, et al. Development and validation of green eating behaviors, stage of change, decisional balance, and self-efficacy scales in college students. *J Nutr Educ Behav*. 2014;46(5):324-33.
25. Monroe JT, Lofgren I, Sartini BL, et al. The Green Eating Project: Web-based intervention to promote environmentally conscious eating behaviors in United States university students. *Public Health Nutrition*. 2015;18(13):2368-78.
26. Chaillé C. Constructivism across the curriculum in early childhood classrooms: Big ideas as inspiration: Allyn & Bacon, 2008.
27. Brand-Gruwel S, Wopereis I, Vermetten Y. Information problem solving by experts and novices: Analysis of a complex cognitive skill. *Computers in Human Behavior*. 2005;21(3):487-508.
28. Wheeler LA, & Collins, S. K. . The influence of concept mapping on critical thinking in baccalaureate nursing students. *J Prof Nurs*. 2003;19(6):339-46.
29. Rosen Y, Tager M. Making Student Thinking Visible through a Concept Map in Computer-Based Assessment of Critical Thinking. *Journal of Educational Computing Research*. 2014;50(2):249-70.
30. Horacek TM, Erdman MB, Byrd-Bredbenner C, et al. Assessment of the dining environment on and near the campuses of fifteen post-secondary institutions. *Public Health Nutr*. 2013;16(7):1186-96.

31. Stupnisky RH, Renaud RD, Daniels LM, et al. The interrelation of first-year college students' critical thinking disposition, perceived academic control, and academic achievement. *Research in Higher Education*. 2008;49(6):513-30.
32. Harlow LL. The essence of multivariate thinking: Basic themes and methods: Routledge, 2014.
33. Bentler PM. EQS Structural Equations Program Manual. Encino, CA: Multivaritate Software Inc., 2006.
34. Şendağ S, Ferhan Odabaşı H. Effects of an online problem based learning course on content knowledge acquisition and critical thinking skills. 2009:132-41.
35. Perry DK, Burgess MH, Sowell BF, et al. Using Competing Narratives to Increase Critical Thinking Abilities. *NACTA Journal*. 2017;61(1):41.
36. Accreditation Council for Education in Nutrition and Dietetics, Commission on Dietetic Registration, Council on Future Practice, Education Committee, Nutrition & Dietetics Educators and Preceptors DPG. 2013.
37. Easterly T, Warner AJ, Myers BE, et al. Skills Students Need in the Real World: Competencies Desired by Agricultural and Natural Resources Industry Leaders. *Journal of Agricultural Education*. 2017;58(4):225-39.
38. Guiller J, Durndell A, Ross A. Peer interaction and critical thinking: Face-to-face or online discussion? *Learning and instruction*. 2008;18(2):187-200.
39. Abrami PC, Bernard RM, Borokhovski E, et al. Instructional interventions affecting critical thinking skills and dispositions: A stage 1 meta-analysis. *Review of Educational Research*. 2008;78(4):1102-34.
40. Dochy F, Segers M, Van den Bossche P, et al. Effects of problem-based learning: A meta-analysis. *Learning and instruction*. 2003;13(5):533-68.
41. Liu OL, Bridgeman B, Adler RM. Measuring learning outcomes in higher education: Motivation matters. *Educational Researcher*. 2012;41(9):352-62.
42. Weiler A. Information-seeking behavior in generation y students: Motivation, critical thinking, and learning theory. *J Acad Libr* 2005;31(46):53.
43. Profetto-McGrath J. The relationship of critical thinking skills and critical thinking dispositions of baccalaureate nursing students. *J. Adv. Nurs.* 2003;43(6):569-77.
44. Abrami PC, Bernard RM, Borokhovski E, et al. Strategies for teaching students to think critically: A meta-analysis. *Review of Educational Research*. 2015;85(2):275-314.

Table 1: Differences in Module 1 and 2 Design Between Critical Thinking Decision Making Framework (CTDM-F) Group and Control Group

	CTDM-F Group	Control Group
Module 1: Animal/Plant Protein		
Topic	Introduced in the form of a problem	Introduced as the topic
Support	T-Chart Mind-Map	None
Decision-Making Activity	Structured fill in the blanks	Text box
Module 2: Organic/Non-Organic		
Topic	Introduced in the form of a problem	Introduced as the topic
Support	T-Chart Mind-Map	None
Decision-Making Activity	Text box	Text box

Table 2: Baseline Demographics by Critical Thinking Decision-Making Framework (CTDM-F) Group and Control Group

Variable	CTDM-F (n=203) mean (std)	Control (n=228) mean (std)	F-Value
Age	19.3 (1.3)	19.4 (1.5)	1.82
Pre-CTD[a]	3.51 (.6)	3.54 (.6)	.50
Pre-GE Behavior[b]	2.72 (.7)	2.76 (.8)	.29
Variable	**CTDM-F (n=203) %**	**Control (n=228) %**	**Pearson Chi-Square**
Gender			.03
Male	26.6	26.0	
Female	73.4	74.0	
Major[c]			.85
Arts and Humanities	42.4	42.4	
STEM	23.6	20.5	
STEM-Health	28.6	31.4	
Undecided	5.4	5.7	
University[d]			1.06
University 1	50.7	55.7	
University 2	49.3	44.3	

[a]CTD= Critical Thinking Disposition, Motivated Strategies for Learning Questionnaire (MSLQ), mean score of five items measured using a 5-point Likert scale: (1) strongly disagree (5) strongly agree.
[b]Pre-GE Behavior= Pre-Green Eating Behavior, 7-item survey, 5-point Likert scale ranging from (1) barely ever to never to (5) almost always.
[c]Arts and Humanities= social sciences, arts, and undecided; STEM Majors= Science, Technology, Engineering, and Math; STEM-Health Majors= nutrition, kinesiology, nursing, pre-med
[d]University 1= University of Rhode Island; University 2= University of North Texas
Continuous variables assessed using ANCOVA, controlling for university
Categorical variables assessed using Pearson Chi-Square

Table 3: Differences in Critical Thinking Decision-Making Framework (CTDM-F) Group Responses and Control Group Responses in Module 2 After Controlling for University

Variable	CTDM-F (n=203)	Control (n=228)	F-Value
CT-DM Score [a] mean (std)	18.1 (7.6)	15.4 (8.4)	14.58**
Number of Evidence-Based Reasons [b] mean (std)	1.7 (1.1)	1.3 (1.0)	15.21**

Variable	CTDM-F (n=203)	Control (n=228)	Pearson Chi-Square
Made a decision (%)			
Yes	91.1	80.3	
No	8.9	19.7	10.17**
Reason (% reported)			
Health	39.5	31.7	3.93
Animal	2.4	1.7	2.04
Price	12.2	9.1	1.94
Economic	4.4	4.3	.00
Environment	50.7	47.0	.62
Other	3.4	4.4	.25
Identified other perspective (%)			
Yes	14.3	18.4	
No	85.7	81.6	1.34

[a]Critical Thinking Decision Making (CT-DM) Score: range from 0-30, 0= no CT-DM and 30=high CTDM
[b]Number of evidence-based reasons used to support decision: range from 0 to 3, higher value = more reasons used to support decision
Continuous variables assessed using ANCOVA, controlling for university
Categorical variables assessed using Pearson Chi-Square
*p<.05
**p<.01

Table 4: Structural Equation Modeling Macro-Level Fit Indices for Direct, Predictive, and Mediational Pathways Explaining Critical Thinking Decision Making Score

Pathway	Macro-Level Fit Indices[d]					
	X^2	df	X^2/df ratio	CFI	RMSEA	X^2 difference
Direct[a]	21.82*	5	4.36	.302	.093	---
Mediational[b]	21.72*	2	10.86	.181	.159	.10
Predictive[c]	14.65*	3	4.88	.516	.100	7.07

[a]Direct pathway from group to critical thinking decision making (CT-DM) score

[b]Mediational pathway with group as independent variable and GE behavior and CTD as mediating variables explaining CT-DM score

[c]Predictive pathway with group, green eating (GE) behavior, and critical thinking disposition (CTD) predicting CT-DM score

[d]Ideal macro-level fit indices parameters: X^2 $p > 0.05$, X^2/df ratio < 4, CFI > 0.90, RMSEA < 0.08, X^2 difference= larger value equates to better fit

*$p < .001$

Figure 1: Prediction Model Pathway with Parameter Estimates for Critical Thinking Disposition Score, Group, and Green-Eating Behavior