Published in final edited form as:

J Sch Health. 2018 January ; 88(1): 15–22. doi:10.1111/josh.12576.

Exploring the associations among nutrition, science, and mathematics knowledge for an integrative, food-based curriculum

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Abstract

Background—Explore associations between nutrition, science, and mathematics knowledge to provide evidence that integrating food/nutrition education in the fourth-grade curriculum may support gains in academic knowledge.

Methods—Secondary analysis of a quasi-experimental study. Sample included 438 students in 34 fourth-grade classrooms across North Carolina and Ohio; mean age 10 years old; gender (I=53.2% female; C=51.6% female). Dependent variable = post-test-nutrition knowledge; independent variables = baseline-nutrition knowledge, and post-test science and mathematics knowledge. Analyses included descriptive statistics and multiple linear regression.

Results—The hypothesized model predicted post-nutrition knowledge ($F(437) = 149.4$, $p < .001$; Adjusted $R^2 = .51$). All independent variables were significant predictors with positive association.

Conclusions—Science and mathematics knowledge were predictive of nutrition knowledge indicating use of an integrative science and mathematics curriculum to improve academic knowledge may also simultaneously improve nutrition knowledge among fourth-grade students. Teachers can benefit from integration by meeting multiple academic standards, efficiently using limited classroom time, and increasing nutrition education provided in the classroom.

Keywords

nutrition; science; mathematics; nutrition knowledge; integration

Since the late 1970s, teachers have faced obstacles to provide nutrition education in their classrooms including an overcrowded curriculum, lack of content knowledge, limited availability of curricula, and varying levels of administrative support.¹⁻⁴ Nutrition educators consistently recommend nutrition education be integrated into core subject areas such as science, mathematics, and language arts⁵⁻⁷ to overcome cited barriers and provide children academic content with relevance to everyday life. In the 1990s the US Department of Agriculture (USDA) promoted nutrition in schools based on the Dietary Guidelines for Americans and the Food Guide Pyramid.^{8,9} By 1996 almost all public schools reported providing nutrition education in the curriculum, although the quality and intensity of the coverage was unknown. From a policy point of view, only 50% of schools with grades K-8, 40% with grades 9-10, and 20% with grades 11-12 were required to provide nutrition education.⁹ The actual percentage of children receiving instruction was, and continues to be, difficult to measure. However, one report from the National Center for Education Statistics revealed the mean number of hours dedicated to nutrition education in K-12 was 13, well below the minimum of 50 hours thought necessary for impact on behavior.^{11,12}

In 2010, the White House released the report: “*Solving the Problem of Childhood Obesity within a Generation*,” nutrition education was mentioned specifically as an area needing improvement in schools, recognizing the amount of time spent on nutrition education had declined.¹³ Since then, the initiation of Michelle Obama's *Let's Move* and President Obama's *Educate to Innovate* campaigns have re-invigorated the efforts of professionals to provide integrative nutrition education in schools.^{14,15} These campaigns provide a unique opportunity for Science, Technology, Engineering, and Mathematics (STEM) and nutrition education professionals to work collaboratively toward achieving improvement of the general public's nutrition, science, and mathematics education.

From a young age, the mind is engaged in actively seeking and assimilating new knowledge.¹⁶ Put simply, children can better understand their world by engaging in science and mathematics learning.^{17,18} In particular, successful experiences with mathematics have been related to early development of positive beliefs related to a child's actual achievement.¹⁹ Science and mathematics education should be a systematic, meaningful part of the early education curriculum if children are to develop the skills and knowledge needed for careers involving science, as well as the interest and confidence to sustain continued engagement and achievement beyond high school.²⁰ As educators, we are aware of the importance of early childhood education in establishing a solid foundation of science and mathematics for improving academic performance in these areas.

Interestingly, food and nutrition can serve as a natural foundation for integrative learning, providing teachers with a vehicle for teaching more difficult subjects to elementary-aged children. Use of this method can enable teachers to introduce multiple topics and improve the quality of education provided through hands-on learning.²¹ Active learning engages children and aids in the acquisition of knowledge and skills.²² This type of learning process

encourages student engagement and ultimately internal motivation to assimilate new information. Developing fun and engaging science and mathematics learning environments for young children can impact their entire K-12 experience and help them to feel confident in pursuing science careers at a young age.²³ Science and/or mathematics investigations can also lead to discussion about the importance of health and nutrition, and inspire students' interest in leading healthy lives and pursuing careers in science professions. Integrating experiential activities involving food can not only help teachers' meet educational goals, but also support children in learning how to make healthy lifestyle choices.²⁴ A successful demonstration that integration of nutrition education in the classroom could improve academic knowledge in science and mathematics might encourage teachers to frequently integrate more nutrition-related content in their classrooms.

For children, a benefit of subject integration is seeing the importance of core content by providing meaning to everyday learning activities.¹ Nutrition and healthy eating are relevant to all age groups, a key component for integrating real-world context into common core subjects.²⁵ Beginning in the late 1990s, studies have demonstrated the benefits of integrative nutrition education on health behaviors.²⁶ For example, hands-on cooking activities have been shown to support active learning, engage children, aid in the acquisition of new information, and help children learn how to make healthy choices related to dietary and lifestyle patterns.^{5,22,24,27,28} Contento et al reported adolescents demonstrated improvement in obesity risk behaviors (eg, physical activity, sweetened beverage consumption) after completion of Choice, Control & Change, an integrative science curriculum that targeted personal agency and autonomous motivation in order to encourage behavior change.²⁹

While past research has demonstrated the health benefits of using an integrative nutrition education curriculum^{7,29-31}, to the authors' knowledge, only two programs have investigated its impact on academic-related knowledge.³²⁻²⁶ Using a repeated measure analysis design, teens involved in "EatFit" experienced significant improvements in mathematical reasoning, and algebraic functions^{32,33} showing nutrition education may positively impact academic knowledge. A second program used a quasi-experimental design to assess the effect of the FoodMASTER Intermediate (FMI) curriculum, an integrative curriculum that uses food as a teaching tool to improve science and mathematics knowledge among fourth grade students. A significant improvement in science, mathematics, and nutrition knowledge was seen in the intervention group. Knowledge gains were also significantly higher in all 3 content areas when compared to a well-matched comparison group.³⁴⁻³⁶ Currently, the literature lacks an exploration of the associations among nutrition, science, and mathematics knowledge. This study presents a secondary multiple regression analysis of nutrition, science, and mathematics knowledge scores collected from fourth-grade classrooms using the FMI curriculum.³⁴⁻³⁶ The regression was used to analyze potential associate overlap among scores and not to establish a definitive causal model.

Methods

Participants

Data for this secondary analysis were collected from 34 fourth-grade classrooms across Ohio (OH) and North Carolina (NC) during the 2009-2010 school year in both intervention

and comparison classrooms. Eighteen fourth-grade classrooms (OH=9; NC=9) were recruited to implement the FMI curriculum (I=Intervention). An additional 16 fourth-grade classrooms (OH=8; NC=8) were recruited to act as comparison classrooms (C=Comparison). Teachers provided parents with informed consent explaining the FMI curriculum, purpose of the study, and data to be collected; assent was also obtained from each consented student. Teachers reported demographic information for participating students including sex, date of birth, and ethnicity.

Intervention classrooms—Teachers within the intervention group committed to implementing all 24 food-based lessons in their classrooms. FMI integrated nutrition, science, and mathematics content into the existing fourth-grade curricula by engaging students in food-based activities (gift cards were provided for the purchase of perishable foods). Teachers with all materials needed to teach each lesson and improve overall fidelity. Consenting/assenting students within the intervention classrooms completed the nutrition, science, and mathematics knowledge exams in the fall prior to beginning FMI, and again in late spring after being exposed to all curricular activities.

Comparison classrooms—Teachers within the comparison classroom did not incorporate the FMI curriculum into their lesson plans. However, consenting/assenting students in comparison classrooms also completed the nutrition, science, and mathematics knowledge exams at the beginning and end of the academic year. Students in comparison classrooms were only exposed to non-food-based nutrition, science, and mathematics curricula as determined by each respective teacher and state-mandated educational content standards. Comparison classroom activities were not documented; however, teachers verbally reported they did not use food as a teaching tool during that academic year.

Procedure and Instruments

For this study, we utilized data from 3 researcher-developed content-specific exams.³⁴⁻³⁶ FMI and its evaluation has been described elsewhere.³⁴⁻³⁷

Data for the secondary analyses were collected from multiple-choice knowledge-based exams.³⁴⁻³⁷ Nutrition knowledge was measured using a 28-item exam with six content areas: food groups (8-items), whole-grains (5-items), fats, food safety and food labels (4-items each), and micronutrients (3-items).³⁶ Science knowledge was measured using a 13 items with questions from 4 of the 8 categories of content standards: *Life Science* (5-items), *Science in Personal & Social Perspectives* (2-items), *Physical Science* and *Science and Technology* (3-items, each).³⁴ Mathematics knowledge was measured using 20-items with questions categorized into four domains: *Operations and Algebraic Thinking* (7-items), *Number and Operations in Base Ten* (2-items), *Number and Operations with Fractions* (3-items), and *Measurement and Data* (8-items).³⁵ Additional details regarding the development of each exam have been previously described including assessment of the tool's content validity, item difficulty and discrimination indexes, and reliability.³⁴⁻³⁶

Data Analysis

For this study, descriptive means and frequencies were calculated for demographic and main study variables; independent *t*-tests and chi-square analyses were used to compare potential demographic differences between intervention and comparison groups. Linear regression and multiple regression analyses were used to examine the association between nutrition, science, and mathematics knowledge scores. A series of linear regression analyses were conducted to identify the relationship strength between variables. A standard multiple regression analysis was constructed to evaluate the ability of science and mathematics knowledge to predict nutrition knowledge. The dependent variable (outcome) was the students' post-test nutrition knowledge. The independent variables (predictors) were baseline nutrition knowledge, and post-test science, and mathematics knowledge. For this study, only post- measures for science and mathematics were utilized to inform their shared variance with post-measure for nutrition. However, both baseline and post-nutrition scores were examined as an independent variable to parse out the variance due to a student's prior knowledge level in nutrition. All multiple regression assumptions were met and no violations of normality, linearity, or homoscedasticity of residuals were observed. The sample size exceeded the minimally adequate level defined by $N = [50 + (8 \times \# \text{ independent variables})]$.³⁸

Finally, this secondary analysis included, by the original study design, students who were in the intervention and comparison groups. Groups were collapsed to study broadly the ability of science and mathematics knowledge to predict nutrition knowledge. However, the relationship between nutrition, science, and mathematics knowledge scores among students in the intervention and comparison groups were examined with a regression analysis to assess group differences that may have occurred as a result of exposure to the FMI curricula. All analyses were performed using Statistical Package for the Social Sciences 21.0.³⁹

Results

A total 438 students were included in the secondary analysis sample. Over half (61.4%; $N=269$) of students received FMI (intervention), with 38.6% ($N=169$) in comparison classrooms. Most (86.1%, 83.3%, 71.6%, 78.1%, 74.4% respectively) instruments were usable for baseline nutrition, post nutrition, baseline and post mathematics, and baseline science and post science knowledge. On average, students were 10 years old ($I=10.04$, $SD=.58$; $C=9.90$, $SD=1.07$; $t=1.93$, $p=.06$) and female ($I=53.2\%$ female; $C=51.6\%$ female; $X^2=.28$, $p=.60$). Students were identified as white (75.6%); with the rest being black/African American (16.2%), Hispanic or Latino (5.0%), and Other (3.2%) ($X^2=6.30$, $p=.61$). Most (63.9%) lived in rural school districts, 30.6% in urban areas, and 5.5% in areas designated "Other".

Descriptive statistics for nutrition, science, and mathematics knowledge scores have been reported previously³⁴⁻³⁶ and are also summarized in Table 1. Regression analysis revealed that the model (baseline nutrition, post-science, and post-mathematics knowledge) significantly predicted post-nutrition knowledge ($F(437) = 149.4$, $p < .001$). In practical terms, the model predicts a 0.34 standardized score increase in post-nutrition knowledge with every one-point increase in post-mathematics knowledge, after controlling for baseline

nutrition, and post-science knowledge. The model also predicted a 0.73 standardized score increase in post-nutrition knowledge for every point increase in post-science knowledge, after controlling for baseline nutrition and post-mathematics knowledge. Comparatively, the model predicted a lower effect for baseline nutrition knowledge, with a 0.31 standardized score increase in nutrition knowledge for every one-point increase in baseline nutrition knowledge. Table 2 presents the multiple regression coefficients and constant. While the constant term was not statistically significant, all three independent variables were statistically significant at the $p < .001$ level. Given these coefficients, the following predictive model is obtained from these data: Post-test Nutrition Knowledge Score = $[.31 * \text{Baseline Nutrition Knowledge Score}] + [.34 * \text{Post-test Mathematics Knowledge Score}] + [.73 * \text{Post-test Science Knowledge Score}]$

The coefficient of determination (Adjusted $R^2 = .51$) suggests this predictive model accounts for a little more than half of the variation in post-test nutrition knowledge scores. Standardized Beta coefficients lend insights into the relative impact of each of the independent variables on the dependent variable. The strongest association was observed for students' post-test science knowledge scores. Post-mathematics knowledge scores were less strongly associated, and baseline nutrition knowledge scores were less influential than either of the other two independent variables.

When conducting the same regression analyses separately for the intervention and comparison groups, statistically significant regression models were obtained ($[F(268) = 111.1; p < .001]$ and $[F(169) = 39.1; p < .001]$, respectively). The Beta coefficient was largest for science in both models. The intervention group model predicted a 0.73 standardized score increase in post-nutrition knowledge for every one-point increase in post-science knowledge scores, after controlling for baseline nutrition knowledge and post-mathematics knowledge. However, the comparison group model only demonstrated a 0.42 standardized score increase in nutrition knowledge for every one-point increase in post-science knowledge. The respective coefficients of determination (Adjusted $R^2 = 55.2\%$ and 40.5% , respectively) further illustrate that a much larger proportion of the total variance for the intervention group compared with the comparison group was explained by baseline nutrition knowledge, post-mathematics knowledge, and post-science knowledge. The difference is marked, as the Adjusted R^2 for the intervention group is almost fifteen percentage points higher.

Discussion

The purpose of this study was to present a secondary multiple regression analysis of nutrition, science, and mathematics knowledge scores collected from fourth-grade classrooms using the FoodMASTER Intermediate curriculum.³⁴⁻³⁶ Overall, results showed that science and mathematics knowledge were significantly predictive of nutrition knowledge, after controlling for baseline nutrition knowledge, indicating an important academic relationship may potentially exist between knowledge domains. For professionals interested in ensuring intermediate school-age children receive food and nutrition education, integration with science and mathematics may be ideal domains, and vice versa without detracting from efforts to ensure students perform well on achievement on standardized

tests.⁴⁰ The finding that post-test nutrition knowledge increased by almost a full point for every one point increase in science knowledge provides further support for the integration of nutrition into science, already recognized as a feasible approach to teach multidisciplinary concepts.⁴¹ More specifically, human nutrition can be related to the Next Generation Science Standards (NGSS) for physical science such as energy transfer and chemical reactions; and life sciences such as matter, energy, and organization of living systems.⁴² Science experiments often are taught using food, but nutrition education topics also can be related to other content areas including but not limited to energy, environment, and health.⁴¹

Improvements in mathematics knowledge resulted in smaller nutrition knowledge increases than did science knowledge. Albeit not as strong as the relationship with science, nutrition and mathematics also may form a natural partnership for learning concepts such as statistics, probability, and proportions; measurement/conversion; problem-solving; and collecting, organizing, describing, displaying, and interpreting data. One example includes using serving sizes of different food groups to teach fractions, decimals, and measurement.¹

The regression analyses for the intervention and comparison groups showed the relationship between nutrition, science, and mathematics knowledge differed, with the intervention group demonstrating stronger associations among the 3 domains of knowledge. Within the subset of students receiving the intervention, a regression coefficient of determination suggested a larger amount of the variability in the post-nutrition knowledge scores was explained by baseline nutrition, science, and mathematics knowledge scores' variance compared to students in the comparison classrooms; Standardized Beta coefficients corroborate this finding. When considering standardized z-scores for all variables, a student's mathematics knowledge z-score was almost three times the science knowledge z-score and almost two times the level of association with their post-test nutrition knowledge z-score, as compared to the comparison group. This secondary analysis illustrates a significant overlap among student knowledge scores in nutrition, science, and mathematics. When designing curricula, educators may wish to leverage this overlap to optimize classroom experience. Teachers can align nutrition science concepts with science and mathematics standards and learning objectives (integration of concepts) without losing classroom time.¹³

Another distinction between the intervention and comparison groups is that for the former, mathematics and science knowledge had a higher level of association with post-nutrition knowledge scores than did baseline nutrition knowledge scores indicating that when an integrative curriculum is used, the students' nutrition knowledge at the end of the year may be highly impacted by the mathematics and science knowledge than by their initial nutrition knowledge. By contrast, when examining students in the comparison group, their nutrition knowledge baseline score was strongly associated with the post-test nutrition knowledge score. Additionally, while science knowledge continued to be predictive of nutrition knowledge for the comparison group, the relationship between mathematics and nutrition knowledge declined in comparison to the intervention group. There are no published works describing the relationship between nutrition, science, and mathematics knowledge so researchers are unable to compare these findings to previous work. However, the current study suggests that in the case of food and nutrition education there are benefits from integrating content with other subject areas to improve student gains in nutrition knowledge.

These findings may serve to encourage teachers who are concerned with student academic performance within core subjects, but are interested in providing more food and nutrition education in their classrooms.

As previous research has indicated, the benefits of integrating nutrition into the classroom are more than just educational. Children must be provided with the tools and knowledge to be responsible for making healthy choices. Curriculum integration allows for meaningful learning and application of school subjects to real-life situations.¹ Nutrition, science, and mathematics naturally form partnerships for effective curriculum integration and can be a feasible option for classroom teachers. This form of learning may be more effective than just memorization in retaining knowledge, developing healthful attitudes toward diet, and promoting healthy behaviors.⁴⁰ Children with good decision-making skills and who can differentiate between reliable and unreliable nutrition information, products, and services will be more likely to make better food choices, and lead a healthy life. Increasing nutrition knowledge may also improve dietary behaviors, thus decreasing the prevalence of childhood obesity. Because schools have little time to implement an additional curriculum area, the best way to provide nutrition education may be to integrate it into other subjects, like mathematics or science.¹ Ultimately, engaging students in hands-on, inquiry-based learning, can better prepare students to understand and apply mathematics and science concepts that may help support a healthy lifestyle.²¹

Limitations

The primary limitation for generalizing the results of this study is that it may not reflect results obtained with other integrative nutrition education curricula or within other grade levels. Further, standardizing the science and mathematics curriculum received in each classroom was not possible. Although teachers were required to meet a set of common academic standards^{43,44} for these core subjects, specific lessons and activities varied by teacher/classroom, and authors did not implement methods to assess variability of science and mathematics curricula among classrooms. Finally, there are other factors that may play a role in student knowledge within the studied content areas. Past research has indicated the evaluation of the impact of nutrition education is weak because researchers have failed to consider the total context in which children learn.⁴⁵ For example, it is important to recognize the influence of socioeconomic factors, in addition to the influence of the family, school, and community environments.^{46,47} In order for nutrition education efforts to produce long-term success, the environment including the, family, school food environment, and community must be supportive by helping to teach and model healthful behaviors to children and adolescents.^{5,48} Particularly, family involvement in nutrition education for school-aged children is important because parents can reinforce information learned at school, and it could impact the dietary behaviors of all family members.^{5,49,50}

Implications for Research and Practice

For more than 40 years, nutrition educators have described food and nutrition as excellent tools for teaching science and mathematics in the K-12 classroom; however, published research to support this idea was lacking. The current study adds to the growing body of

literature providing evidence that improving science and mathematics education may also help to enhance nutrition knowledge, a pre-requisite to achieving a healthy weight and preventing chronic disease. The presented statistical models suggest there is a strong association among knowledge in nutrition, science, and mathematics. In combination with prior research, these findings can be used to convince teachers and administrators that children's academic knowledge and health can simultaneously be improved by integrating food and nutrition education in their curricula. Integrated curricula using nutrition as the underlying context may result in improved student performance on standardized testing, while simultaneously increasing student exposure to nutrition education in the classroom environment.

More research is needed to further explore the relationship between nutrition education and academic knowledge with other forms of integrative nutrition education curricula across K-12 classrooms to build support for inclusion of nutrition education in the school environment; however, nutrition professionals and K-12 educators should begin working together now to improve integration of science, mathematics, and nutrition education in the K-12 classroom. At the local level, nutrition professionals should form collaborations with K-12 educators in their local communities to serve as advocates for nutrition education in the K-12 setting, and human resources for the K-12 teacher interested in integrating nutrition concepts in their classroom. Further, professional development opportunities should be developed and made available to teachers interested in integrating science, mathematics, and nutrition concepts with emphasis placed on hands-on learning and alignment with current educational standards. Nutrition professionals can serve as a key resource during the development and/or delivery of teacher professional development in this area. At the state or federal level, nutrition professionals should actively promote the benefits of integrating science, mathematics, and nutrition in the classroom (e.g. maximizing classroom time, improved understanding of nutrition, potential long-term health benefits for children) to K-12 teachers, administrators, and parents. Collaborations between nutrition professionals and K-12 educators should be formed to align nutrition content with existing science and mathematics standards to provide clearer guidance to all K-12 teachers on how to best integrate science, mathematics, and nutrition concepts. Aligning current and newly developed K-12 nutrition education materials with current science and mathematics standards at the state and federal level would also ensure existing educational resources are available to teachers. Finally, nutrition education researchers should continue building evidence to support the integration of science, mathematics, and nutrition in the K-12 classroom. Future studies investigating this area should include a randomized experimental design at the school or district level to assess the longitudinal effect of using an integrative nutrition education curriculum on academic knowledge.

Human Subjects Approval Statement

The East Carolina University Institutional Review Board approved all study protocols and methods.

Acknowledgments

FoodMASTER is supported by a Science Education Partnership Award (SEPA) from the National Institutes of Health (NIH). The content is solely the responsibility of the authors and does not represent the official views of the NIH. Authors would like to thank Jana Hovland for her work with program implementation and data collection, and the teachers and students for their participation in the study.

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Table 1
Baseline and Post-test Scores Combined and by Intervention/Comparison Subgroups for
Nutrition Knowledge, Science Knowledge, and Mathematics Knowledge (N = 438)

Variable Name	Combined	Intervention	Comparison
	Mean (S.D.)	Mean (S.D.)	Mean (S.D.)
Nutrition Knowledge ^a			
Baseline	14.77 (3.77)	15.35 (3.69)	13.86 (3.74)
Post	18.18 (4.69)	19.98 (4.29)	15.33 (3.81)
Science Knowledge ^b			
Baseline	8.41 (2.15)	8.37 (2.10)	8.48 (2.26)
Post	9.53 (2.25)	10.00 (2.08)	8.78 (2.31)
Mathematics Knowledge ^c			
Baseline	13.10 (4.36)	13.20 (4.17)	12.93 (4.66)
Post	15.66 (3.84)	16.21 (3.58)	14.79 (4.09)

^a28 items¹²

^b20 items¹⁰

^c20 items¹¹

Table 2

Multiple Regression Coefficients and Constants for the Combined Sample and Intervention/Comparison Subgroups Models Using Baseline Nutrition Knowledge, Post-Science Knowledge, and Post-Mathematics Knowledge to Predict Post-Nutrition Knowledge (N = 438)

Variable Name	B	SE B	β	t	p
MODEL 1: Combined Sample (N = 438)					
Dependent Variable					
Post-Nutrition Knowledge	1.38	.81	-	1.70	.09
Independent Variables					
Pre-Nutrition Knowledge	.31	.05	.25	6.27	.00
Post-Science Knowledge	.73	.09	.35	8.47	.00
Post-Mathematics Knowledge	.34	.05	.28	6.42	.00
MODEL 2: Intervention Subgroup (N = 269)					
Dependent Variable					
Post-Nutrition Knowledge	1.60	1.03	-	1.55	.12
Independent Variables					
Pre-Nutrition Knowledge	.23	.05	.20	4.27	.00
Post-Science Knowledge	.73	.10	.36	7.55	.00
Post-Mathematics Knowledge	.47	.06	.39	8.01	.00
MODEL 3: Comparison Subgroup (N = 169)					
Dependent Variable					
Post-Nutrition Knowledge	4.34	1.04	-	4.17	.00
Independent Variables					
Pre-Nutrition Knowledge	.35	.07	.35	4.81	.00
Post-Science Knowledge	.42	.13	.25	3.3	.00
Post-Mathematics Knowledge	.16	.08	.18	2.13	.03