과학교육연구지, 40권 1호, pp. 1-16 (2016.4) Jour. Sci. Edu, Vol. 40, No. 1, 1-16 (2016.4)

Students' Knowledge, Acceptance of Theory of Evolution and Epistemology: Cross-sectional Study of Grade Level Differences

Sun Young Kim*
Chosun University*

Abstract : The purpose of this study is to explore the variables of knowledge, acceptance of theory of evolution and epistemology that could be keys for teaching and learning the theory of evolution within school contexts, and to suggest instructional tips for teaching evolution in relation to the grade levels of education. This cross-sectional study examined the grade level differences (8th, 11th, and preservice teachers) of four variables: evolutionary knowledge; acceptance of theory of evolution; and both domain-specific epistemology (nature of science in relation to evolution) and context-specific epistemology (scientific epistemological views) and their relationships. This study, then, built conceptual models of each grade level students' acceptance of theory of evolution among the factors of evolutionary knowledge and epistemology (both domain-specific and context-specific). The results showed that the scores of evolutionary knowledge, evolution in relation to NOS, and scientific epistemology increased as the grade levels of education go up($p<.05$) except the scores of acceptance of theory of evolution($p>.05$). In addition, the 8th graders' and the 11th graders' acceptance of evolutionary theory was most explained by 'evolution in relation to NOS', while the preservice teachers' acceptance of evolutionary theory was most explained by evolutionary knowledge. Interestingly, 'scientific epistemological views' were only included for the 8th graders, while evolutionary knowledge and 'evolution in relation to NOS' (context-specific epistemology) were included in explaining all the level of students' acceptance of evolutionary theory. This study implicated that when teaching and learning of the theory of evolution in school contexts, knowledge, acceptance of evolutionary theory and epistemology could be considered appropriately for the different grade levels of students.

keywords : theory of evolution, epistemology, nature of science, knowledge, acceptance

I. Introduction

The theory of evolution represents a major scientific theory in biology with an extensive and fundamental explanatory power. The importance of teaching biological evolution has emphasized as one of the most unifying ideas in biology (Dobzhansky, 1973). A scientific theory is usually recognized as fundamental explanatory power with a high degree of acceptance, but not in evolutionary theory (Clough, 1994; Hokayem & BouJaoude, 2008). Even though the theory of evolution is considered as a central theme in biology, a large percentage of individuals fail to either understand or accept the theory of evolution due to religious affiliation, age, gender, education, and region of country (Hofer *et al.*, 2011). Especially, students' religiosity and acceptance of evolutionary theory, as well as understanding of evolutionary theory are negatively correlated (Heo, 2010; Kim & Cha,

*Corresponding author: Sun Young Kim (sykim519@chosun.ac.kr)
**This study was supported by research fund from Chosun University, 2014.
***2016년 1월 26일 접수, 2016년 4월 8일 수정원고 접수, 2016년 4월 22일 채택

2014; Nehm *et al.*, 2009). Kim (2014), for example, reported that the Christian high school students represent the low acceptance and understanding of evolutionary theory compared to the non-Christians, with no gender differences. Even though how to teach the theory of evolution is a critical concern in science classrooms, considering each student's religious belief is inadequate when teaching and learning the theory of evolution within school contexts.

Number of studies have examined factors affecting students' acceptance or understanding of theory of evolution (e.g., Deniz, Donnelly, & Yilmaz, 2008; Ha *et al.*, 2012; Rutledge & Mitchell, 2002; Trani, 2004). The factors that each study examined vary from study to study, such as number of credit hours in biology and completion of a course in evolution, and completion of a course in the philosophy of science (Rutledge & Mitchell, 2002), epistemological belief, thinking dispositions, and parents' educational level (Deniz *et al.*, 2008), and feeling of certainty (Ha *et al.*, 2012). In addition, several previous studies maintain that a sophisticated understanding of nature of science is related to learners' acceptance and understanding of evolutionary theory (Clough, 1994; Dagher & BouJaoude, 1997; Johnson & Peebles, 1987; Scharmann, 1990). Trani (2004) further argues that the lack of understanding of the evolutionary theory as well as the lack of understanding of the basic nature of science results in the low level of acceptance of evolutionary theory.

Alters and Nelson (2002) maintain that teaching and learning of the theory of evolution is not typically effective enough in school contexts. Among the various factors that hinder students' understanding and accepting the theory of evolution, epistemology is the one of important factors that teachers need to consider when teaching and learning of evolutionary theory in science classrooms. Hofer *et al.* (2011), for example, argue that inadequate training in scientific literacy and an underdeveloped epistemic understanding of science may be the cause of the failure of a vast number of Americans to accept the basic premises of evolution.

Personal epistemology is defined as individuals' beliefs about the nature of knowledge and knowing (Hoper & Pintrich, 1997). Students' epistemological beliefs are used as alternative interpretive lens in understanding their ideas (Hammer & Elby, 2002). Demastes *et al.* (1995) argue that epistemological approach to science could play a role as the strongest or a secondary controlling factor to the personal emotions invested in the topic. A growing body of research demonstrated that students have both generalized epistemological worldviews and specific discipline-based epistemic beliefs (Hofer, 2000). Domain-general epistemic beliefs mean that one's stance toward knowing and knowledge is presumed to transcend the topic or field. On the contrary, domain-specific levels of epistemic beliefs have focused on domains as the equivalent of academic disciplines, such as beliefs about math, history or science. In addition, along with domain-general and domain-specific epistemology, Hammer and Elby (2002) maintained that personal epistemology should be considered as context-specific. They argued that even holding the putative topic fixed, at least some variations must exist with context. Two previous studies, Deniz *et al.*

(2008) and Sinatra *et al.* (2003), measured domain-general epistemology to examine whether epistemological belief is related to acceptance of evolutionary theory. Both studies (Deniz *et al.*, 2008; Sinatra *et al.*, 2003) did not find the relation between acceptance of evolutionary theory and epistemological belief. This study, thus, postulated that students' acceptance of theory of evolution is closely related to domain-specific or context-specific epistemology rather than domain-general epistemology.

The previous studies regarding the understanding and acceptance of evolutionary theory have conducted with college level of students (e.g., Dagher & BouJaoude, 1997; Johnson & Peeples, 1987; Sinatra *et al.*, 2003), preservice teachers (e.g., Deniz *et al.*, 2008; Ha *et al.*, 2012; Im *et al.*, 2007; Kim & Nehm, 2011), biology teachers (e.g., Nehm *et al.*, 2009; Rutledge & Mitchell, 2002; Rutledge & Warden, 2000; Trani, 2004), and high school students (e.g., Kim, 2014). Few cross-sectional studies were conducted with different grade levels of students. This study focused to explore the variables of knowledge, acceptance of evolution, and both domain-specific and context-specific epistemologies that could be keys for school evolution education, and to suggest instructional tips for teaching evolution in relation to the grade levels of education. This study, therefore, explored (1) the grade level differences (8th, 11th and preservice biology teachers) of evolutionary knowledge, acceptance, and epistemological beliefs, (2) the relation of evolutionary knowledge, acceptance, and epistemological beliefs of each grade level students, and (3) finally to what extent these variables affect each grade level students' acceptance of theory of evolution.

II. Research Procedures and Questions

This cross-sectional study embarks on examining the grade level differences (8th, 11th, and preservice biology teachers) of the variables of evolutionary knowledge, acceptance of evolution, and both domain-specific and context-specific epistemologies (scientific epistemological views; and evolution in relation to NOS) and their relationships. Then, this study purports to build conceptual models of each grade level students' acceptance of theory of evolution among the factors of evolutionary knowledge and both domain-specific and context-specific epistemological beliefs (Fig. 1). This study attempts to answer the following research questions:

1. How do students' differ in their evolutionary knowledge, acceptance of evolution, and both domain-specific (scientific epistemological views) and context-specific epistemological beliefs (evolution in relation to NOS) according to the grade levels of education?
2. How do students' differ in the relationships of evolutionary knowledge, acceptance, and both domain-specific (scientific epistemological views) and context-specific epistemological beliefs (evolution in relation to NOS) according to the grade levels of education?
3. Are there any differences according to the levels of education in the variables (e.g., evolutionary knowledge, evolution in relation to NOS, and scientific epistemological view) that dedicate to predict the acceptance of evolutionary theory?

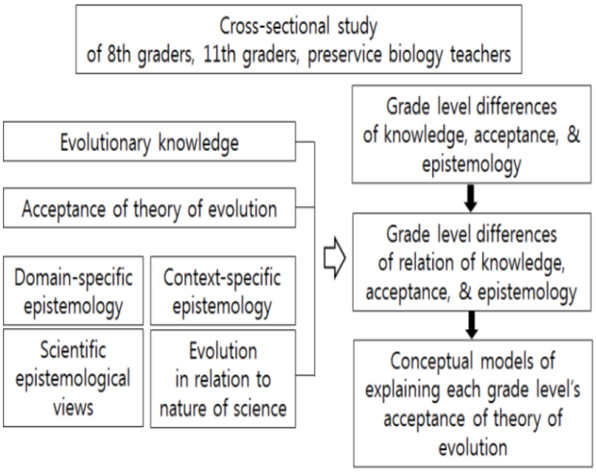

Figure 1. Research variables and procedures

II. Methodology

1. Participants and Context of the Study

A total of 642 students participated in this study. Their levels were the 8th graders (n=415), the 11th graders (n=159), and the preservice biology teachers (n=68). The 8th graders were from two public middle schools located on the metropolitan city. These middle school students did not learn the unit of evolution when we administered the survey. This study selected the 8th graders because they did not learn the theory of evolution in the school, but they have preconceptions on the concepts of evolution, mutation, and so on, through TV animation and science books (Ha & Cha, 2006). The 11th graders from a high school located on the metropolitan city already learned the unit of evolution at their 9th grade. Finally, the preservice biology teachers, from two universities, were affiliated with the department of biology education, and were their third year of undergraduate studies. These preservice teachers completed general biology courses that cover the theory of evolution.

2. Instrument and Measures

1) Measure of acceptance of theory of evolution

The participants' acceptance of evolution was assessed using the MATE (Measure of Acceptance of Theory of Evolution) (Rutledge & Warden, 1999). The instrument composes of 20 items assessing perceptions of evolutionary theory's scientific validity, ability to explain phenomena, and acceptance within the scientific community (e.g., 'Evolution is a scientifically valid theory', 'Evolutionary theory generates testable predictions with respect to the characteristics of life', 'Much of the scientific community doubts if evolution occurs'). Rutledge and Warden (1999) reported that the content validity of the MATE was established by five university professors with expertise in the fields of evolutionary biology, science education, and philosophy of science. The Cronbach's α for this sample was 0.802.

2) Evolutionary knowledge

Students' evolutionary knowledge was measured by the ECK (Evolution Content Knowledge) instrument (Nehm & Schonfeld, 2007). The ECK instrument with a five-point Likert scale consists of 8 items (e.g., 'Chance cannot be a key factor in the origin of complex organisms', 'Mutations are harmful and therefore cannot give rise to new characteristics'). Nehm and Schonfeld (2007) established the validity of ECK by reporting the positive and significant correlation of ECK scores with a separately administered essay scores that asked knowledge about evolution. The Cronbach's alpha for this sample was 0.672.

3) Evolution in relation to the nature of science

The context-specific epistemology, in this study 'evolution in relation to nature of science', was measured using the ENOS instrument (Nehm & Schonfeld, 2007). This measure consists of 9 items (e.g., 'As evolution cannot be observed, it is outside the realm of science', 'Evolution is weaker than many other scientific concepts because it is only a theory'). The validity of this instrument was established by the significant positive correlation between the ENOS scores and students' nature of science related to evolution essay scores (Nehm & Schonfeld, 2007). The reliability measured by the Cronbach α was 0.682 for our sample.

4) Scientific epistemological views

In order to explore students' views of domain-specific epistemology, the scientific Epistemological Views (SEVs) developed by Tsai and Liu (2005) was employed in this study. This instrument consists of 19 items on a five-point Likert scale and includes five subscales: the role of social negotiation on science, the invented and creative reality of science, the theory-laden exploration of science, the cultural impacts on science, and the changing and tentative features of science. The reliability for our sample was 0.767.

5) Data analyses

The ANOVA (analyses of variance) was used to explore differences of each variable (e.g., acceptance of theory of evolution, evolutionary knowledge, evolution in relation to nature of science, scientific epistemological views) according to the grade levels of education. The Pearson correlation was used to measure the degree of association among variables. Finally, this study also used the step-wise multiple regression analysis within each level of education (e.g., 8th graders, 11th graders, and preservice biology teachers).

III. Result and Discussion

This cross-sectional study explored if students' knowledge, acceptance of evolutionary theory, both domain-specific and context-specific epistemology (e.g., the domain-specific epistemology which is epistemological views toward science and the context-specific epistemology which is evolution in relation to nature of science) and their relationships differ according to students' grade levels of education. Further, this study examined which variables dedicate to predict each grade level students' acceptance of theory of evolution. The variables used by this study were the acceptance of the theory of evolution measured by MATE, the evolutionary knowledge measured by ECK, the evolution in relation NOS measured by ENOS, and the epistemological views toward science measured by SEVs. This study reveals that the students tend to increase their scores of evolutionary knowledge, evolution in relation to NOS, and scientific epistemological views as their grade levels of education go up except the scores of acceptance of evolutionary theory (Table 1).

1. Differences of Knowledge, Acceptance of Theory of Evolution, and Epistemological Beliefs in relation to the Grade Levels of Education

1) Evolutionary knowledge in relation to the grade levels of education

The ANOVA of evolutionary knowledge measured by the ECK scores showed a significant main effect of the grade level of education (F[2, 640]=40.750, p<0.01) (Table 2). According to the Post hoc test result, the significant differences were found between the 8th graders and the 11th graders, and between the 11th graders and the preservice biology teachers, indicating that the mean scores significantly increased as the grade level of education goes up (Table 3). Our samples of 8th, 11th, and preservice teachers differed in their learning of evolution in biology course. Rutledge and Mitchell (2002) similarly found the significant association between the acceptance of theory of evolution and the completion of a course in evolution.

Table 1. The descriptive statistics of acceptance, knowledge, and epistemological beliefs across the grade levels of education

	MATE		ECK		Epistemological beliefs ENOS		Epistemological beliefs SEVs	
	M	SD	M	SD	M	SD	M	SD
8th graders (n=415)	64.14	8.83	25.74	2.89	28.46	3.44	63.26	6.08
11th graders (n=159)	64.27	7.84	27.30	3.23	29.26	3.17	67.40	6.97
Preservice biology teachers (n=68)	71.29	9.21	28.94	3.36	30.88	3.59	71.38	7.14

Note. MATE, Measure of Acceptance of the Theory of Evolution (Total score=100); ECK, Evolution Content Knowledge (Total score=40); ENOS, Evolution in relation to NOS (Total score=45); SEVs, Scientific Epistemological Views(Total score=95)

Table 2. The ANOVA results of ECK scores according to the grade levels of education

	Sum of Squares	*df*	Mean Square	*F*	*Sig.*
Between Groups	745.058	2	372.529	40.750	.000**
Within Groups	5850.833	640	9.142		
Total	6595.891	642			

** p<0.01; Note. ECK, Evolution Content Knowledge

Table 3. The pairwise comparison results of ECK score differences according to the grade levels of education

Level of Education		Mean Difference (I-J)	Std. Error	*Sig.*	95% Confidence Interval	
					Lower Bound	Upper Bound
8th	11th	-1.555	.282	.000**	-2.11	-1.00
	Preservice biology teachers	-3.201	.395	.000**	-3.98	-2.42
11th	8th	1.555	.282	.000**	1.00	2.11
	Preservice biology teachers	-1.646	.438	.000**	-2.51	-.79

$^{**}p<0.01$; Note. ECK, Evolution Content Knowledge

2) Acceptance of theory of evolution in relation to the grade levels of education

The ANOVA for the MATE scores uncovered a significant main effect of the grade level of education ($F[2, 640]=20.675$, $p<0.01$) (Table 4). The Post hoc tests showed a significant difference of MATE scores between the 11th graders and the preservice biology teachers ($p<0.01$), but no difference between the 8th graders and the 11th graders ($p>0.05$) (Table 5). The preservice teachers displayed a significantly higher mean score than the 8th and the 11th graders. Notably, there is almost no MATE score difference between the 8th ($M=64.14$; $SD=8.83$) and the 11th graders ($M=64.27$; $SD=7.84$). Even though the students' scores of evolutionary knowledge gradually increased as the grade level of education goes up, no difference of acceptance of evolutionary theory was found between the 8th and the 11th graders. This result supported the previous studies that maintain no relation between evolutionary knowledge and acceptance (Bishop & Anderson, 1990; Brem *et al.*, 2003; Demastes e*t al.*, 1995; Park, 2012; Sinatra *et al.*, 2003).

Table 4. The ANOVA results of MATE scores according to the grade levels of education

	Sum of Squares	*df*	Mean Square	*F*	*Sig.*
Between Groups	3084.886	2	1542.443	20.675	.000**
Within Groups	47746.679	640	74.604		
Total	50831.565	642			

$^{**}p<0.01$; Note. MATE, Measure of Acceptance of the Theory of Evolution

Table 5. The pairwise comparison results of MATE score differences according to the grade levels of education

Level of Education		Mean Difference (I-J)	Std. Error	*Sig.*	95% Confidence Interval	
					Lower Bound	Upper Bound
8th	11th	-.133	.805	.868	-1.71	1.45
	Preservice biology teachers	-7.157	1.130	.000**	-9.38	-4.94
11th	8th	.133	.805	.868	-1.45	1.71
	Preservice biology teachers	-7.024	1.252	.000**	-9.48	-4.57

**p<0.01; Note. MATE, Measure of Acceptance of the Theory of Evolution

3) Epistemological beliefs, both context-specific and domain-specific, in relation to the grade levels of education

The ANOVA results of context-specific epistemology, evolution in relation to NOS, revealed that there was a significant main effect of the grade levels of education (F[2, 640]=16.104, p<0.01)(Table 6). According to the Post hoc test result, there was a significant difference between the 8th graders and the 11th graders (p<0.05), and the 11th graders and the preservice biology teachers (p<0.01), indicating that the mean scores of 'evolution in relation to NOS' significantly increased as the grade level of education goes up (Table 7).

In terms of domain-specific epistemology measured by scientific epistemological views (SEVs), there was a significant main effect of the grade levels of education (F[2, 639]=59.618, p<0.01) (Table 8). The Post hoc test results revealed a significant difference between the 8th graders and the 11th graders (p<0.01), as well as between the 11th graders and the preservice biology teachers (p<0.01), indicating that the mean scores significantly increase as the grade level of education goes up (Table 9). Sinatra *et al.* (2003) argue that epistemological beliefs are changeable relating to learners' education. A learner's epistemological belief

Table 6. The ANOVA results of ENOS scores according to the grade levels of education

	Sum of Squares	*df*	Mean Square	*F*	*Sig.*
Between Groups	369.937	2	184.969	16.104	.000**
Within Groups	7351.186	640	11.486		
Total	7721.123	642			

**p<0.01; Note. ENOS, Evolution in relation to NOS

Table 7. The pairwise comparison results of ENOS score differences according to the grade levels of education

Level of Education		Mean Difference (I-J)	Std. Error	*Sig.*	95% Confidence Interval Lower Bound	Upper Bound
8th	11th	-.807	.316	.011*	-1.43	-.19
	Preservice biology teachers	-2.426	.443	.000**	-3.30	-1.56
11th	8th	.807	.316	.011*	.19	1.43
	Preservice biology teachers	-1.618	.491	.001**	-2.58	-.65

*p<0.05;**p<0.01; Note. ENOS, Evolution in relation to NOS

Table 8. The ANOVA results of SEVs scores according to the grade levels of education

	Sum of Squares	*df*	Mean Square	*F*	*Sig.*
Between Groups	4921.769	2	2460.885	59.618	.000**
Within Groups	26376.468	639	41.278		
Total	31298.237	641			

**p<0.01; Note. SEVs, Scientific Epistemological Views

affects dealing a controversial issue (Kardash & Scholes, 1996). A sophisticated understanding of scientific epistemology is related to learners' acceptance of evolutionary theory, allowing students think over a scientific theory, methodologies of science, values of evidences, and difference of science and religion (Rutledge & Warden, 2000; Scharmann, 1990).

2. Associations among Knowledge, Acceptance of Theory of Evolution, Epistemological Beliefs according to the Grade Levels of Education

The Pearson correlation analyses were used to explore the relationships among the variables of knowledge, acceptance of evolutionary theory, and both domain-specific (scientific epistemological views) and context-specific epistemological beliefs (evolution in relation to NOS) according to the grade levels of education (Table 10). The 8th and 11th graders represented the strongest relationship between MATE and ENOS, indicating that these students with higher scores of 'evolution in relation to NOS' were more likely to accept the theory of evolution. On the other hand, the preservice biology teachers represented the strongest relation

Table 9. The pairwise comparison results of SEVs score differences according to the grade levels of education

Level of Education		Mean Difference (I-J)	Std. Error	*Sig.*	95% Confidence Interval Lower Bound	Upper Bound
8th	11th	-4.134	.599	.000**	-5.31	-2.96
	Preservice biology teachers	-8.120	.841	.000**	-9.77	-6.47
11th	8th	4.134	.599	.000**	2.96	5.31
	Preservice biology teachers	-3.986	.931	.000**	-5.81	-2.16

**$p<0.01$; Note. SEVs, Scientific Epistemological Views

Table 10. The correlation of ECK, ENOS, MATE and SEVs

	8th graders	11th graders	Preservice biology teachers	Total
MATE-ENOS	.578**	.545**	.585**	.590**
MATE-ECK	.453**	.437**	.662**	.498**
MATE-SEVs	.251**	.288**	.421**	.326**
ENOS-ECK	.481**	.269**	.435**	.459**
ENOS-SEVs	.162**	.222**	.244*	.252**
ECK-SEVs	.251**	.288**	.421**	.326**

*$p<0.05$;**$p<0.01$; Note. ECK, Evolution Content Knowledge; ENOS, Evolution in relation to NOS; MATE, Measure of Acceptance of the Theory of Evolution; SEVs, Scientific Epistemological Views

between MATE and ECK with the higher scores of evolutionary knowledge more likely to accept the theory of evolution.

There was a low association between MATE scores and SEVs scores compared to the relationship between MATE and ENOS for each group of the 8th graders, the 11th graders, and the preservice teachers. In particular, the context-specific epistemology measured by ENOS and the domain-specific epistemology measured by SEVs were significantly associated each other but its magnitude was less than .250 for each group (8th, 11th, and preservice teachers). This result indicates that the acceptance of theory of evolution is less associated with the scientific epistemological views (domain-specific epistemology) than the evolution in relation to NOS (context-specific epistemology). It is also notable that the magnitude between ‘the acceptance of theory of evolution’ (MATE) and ‘evolutionary knowledge’ (ECK) is greater than the magnitude between ‘the acceptance of theory of evolution’ (MATE) and ‘scientific epistemological views’ (SEVs) for all the groups (8th, 11th, and preservice teachers) of

Table 11. Multiple regression analyses for variables explaining the 8th graders' acceptance of evolutionary theory

Model	Unstandardized Coefficients		Standardized Coefficient		
	B	*SE B*	*β*	*t*	Adjusted R^2
Step 1					
Constant	21.83	2.96		7.387**	.333
ENOS	1.49	.10	.58	14.418**	
STEP 2					
Constant	11.91	3.46		3.439**	.372
ENOS	1.21	.11	.47	10.564**	
ECK	.70	.14	.23	5.118**	
STEP 3					
Constant	2.95	4.43		.665	.385
ENOS	1.19	.11	.46	10.500**	
ECK	.61	.14	.20	4.459**	
SEVs	.18	.06	.13	3.186**	

** $p<0.01$; SE B = standard error of B
Note. ENOS, Evolution in relation to NOS; ECK, Evolution Content Knowledge; SEVs, Scientific Epistemological Views

Table 12. Multiple regression analyses for variables explaining the 11th graders' acceptance of evolutionary theory

Model	Unstandardized Coefficients		Standardized Coefficient		
	B	*SE B*	*β*	*t*	Adjusted R^2
Step 1					
Constant	24.81	4.87		5.091**	.292
ENOS	1.35	.17	.54	8.142**	
STEP 2					
Constant	10.12	5.49		1.844	.380
ENOS	1.14	.16	.46	7.086**	
ECK	.76	.16	.31	4.814**	

** $p<0.01$; SE B = standard error of B
Note. ENOS, Evolution in relation to NOS; ECK, Evolution Content Knowledge

participants. This result indicates that the theory of evolution is a context-specific topic (Kim, 2015), and biology teachers specifically need to mention the meaning of a scientific theory and evidences within the context of the theory of evolution along with evolutionary knowledge.

3. Testing Model Fit

We used the step-wise multiple regression analyses to examine which variables dedicate to predict acceptance of theory of evolution within each level of education. For the middle school students, 'evolution in relation to NOS' (ENOS) accounted for 33.3 % of the variance in the acceptance of evolutionary theory. The addition of evolutionary knowledge (ECK) to the regression model increased the variance explained: 'evolution in relation to NOS' and evolutionary knowledge together accounted for 37.2% of the acceptance of evolution. 'Evolution in relation to NOS' (ENOS), evolutionary knowledge (ECK) and scientific epistemological views (SEVs) all together explained 38.5% of the acceptance of evolution (Table 11). It is interesting that 'scientific epistemological views' (SEVs) were only included in the variables explaining students' acceptance of evolutionary theory for the 8th graders, but not for the 11th graders and the preservice teachers (Table 11, Table 12 & Table 13).

For the high school students, 29.2% of the variance of acceptance of theory of evolution was explained by 'evolution in relation to NOS' (ENOS). 'Evolution in relation to NOS' (ENOS) and evolutionary knowledge (ECK) together explained 38.0% of the acceptance of theory of evolution (Table 12). On the other hand, for the preservice biology teachers, about 42.9% of the acceptance of evolutionary theory (MATE) is explained by evolutionary knowledge (ECK). The addition of 'evolution in relation to NOS' (ENOS) to evolutionary knowledge (ECK) accounted for 53.3% of the variance in the acceptance of evolution (Table 13).

It is notable that the preservice teachers' acceptance of evolutionary theory was most explained by evolutionary knowledge, whereas the 8th and the 11th graders' acceptance of theory of evolution was most explained by 'evolution in relation to NOS' which is context-specific epistemology. Sinatra *et al.* (2003) argue that knowledge must reach a critical level to influence students' acceptance of evolution, and their sample did not possess enough levels of knowledge to find any relation between the knowledge of evolution and acceptance of evolutionary theory. Brem *et al.* (2003) also did not find any relation between knowledge of evolution and acceptance of evolutionary theory. From the

Table 13. Multiple regression analyses for variables explaining the preservice biology teachers' acceptance of evolutionary theory

Model	Unstandardized Coefficients *B*	Unstandardized Coefficients *SE B*	Standardized Coefficient *β*	*t*	Adjusted R^2
Step 1					
Constant	18.75	7.38		2.542*	.429
ECK	1.82	.25	.66	7.172**	
STEP 2					
Constant	2.36	7.85		.300	.533
ECK	1.38	.25	.50	5.419**	
ENOS	.94	.24	.37	3.959**	

*$p<0.05$; **$p<0.01$; SE B = standard error of B

Note. ECK, Evolution Content Knowledge; ENOS, Evolution in relation to NOS standpoint of Sinatra *et al.* (2003)'s assertion, the participants of Brem *et al.* (2003) came from various majors (e.g., humanities, engineering, social science) and may not possess enough knowledge to affect students' acceptance of evolutionary theory. Even though we cannot compare knowledge scores with these studies since each study used different instruments, the preservice teachers in this study might reach the critical point that Sinatra *et al.* (2003) asserted.

IV. Conclusion and Implication

This cross-sectional study examined the difference of students' acceptance of theory of evolution, evolutionary knowledge, and both domain-specific (scientific epistemological views) and context-specific epistemology (evolution in relation to NOS) in relation to the students' grade levels of education (8th, 11th, and preservice biology teachers). The results reveal that the students' scores of evolutionary knowledge and epistemology (both of evolution in relation to NOS, and scientific epistemological views) increased as the grade levels of education go up except the scores of acceptance of evolutionary theory. This result implicates that the acceptance of evolutionary theory is another issue in teaching and learning the theory of evolution within classroom contexts.

In addition, the 8th and the 11th graders represented the strongest relation between the acceptance of evolutionary theory and evolution in relation to NOS, while the preservice biology teachers represented the strongest relation between the acceptance of evolutionary theory and evolutionary knowledge. Interestingly, the magnitude of the relation of 'the evolution in relation to NOS' and 'the scientific epistemological views' is very small, indicating less than .250 for each group. These results implicate that evolutionary epistemology differs from scientific epistemological views. This study suggests that when teaching and learning the evolutionary theory, epistemology needs to be dealt within the context of the development of theory of evolution. School textbooks also need to specifically describe how the theory of evolution has developed within scientific community and what the evidences of evolutionary theory are. Further, providing students with opportunity of decision making on scientific values of evolutionary theory could be supportive rather than mentioning general scientific epistemology such as the meaning of scientific theory, facts, and evidences when teaching and learning the theory of evolution.

The context-specific epistemology, 'evolution in relation to NOS', most explained the 8th and the 11th students' acceptance of theory of evolution. On the other hand, the preservice biology teachers' acceptance of evolutionary theory was most explained by evolutionary knowledge, implicating that the high level of evolutionary knowledge increases the level of acceptance of evolutionary theory. Interestingly, scientific epistemological views played a role in explaining students' acceptance of evolutionary theory only for the 8th graders, but not for the 11th and the preservice biology teachers.

This study suggests that teachers could provide instructional intervention that explicitly discusses what kinds of observations and tests have conducted by scientists to produce the theory of evolution. Active classroom discussions may help students judge the validity of evolutionary theory. When teaching and learning of the theory of evolution in science classrooms, teachers need to consider students' evolutionary knowledge, acceptance, and both domain-specific epistemology and context-specific epistemology appropriately for the different grade levels of students.

Reference

Alters, B. J., & Nelson, C. E. (2002). Perspective: Teaching evolution in higher education. *Evolution, 56*(10), 1891-1901.

Bishop, B. A., & Anderson, C. W. (1990). Student conceptions of natural selection and its role in evolution. *Journal of research in science teaching*, *27*(5), 415-427.

Brem, S. K., Ranney, M., & Schindel, J. (2003). Perceived consequences of evolution: College students perceive negative personal and social impact in evolutionary theory. *Science Education*, *87*(2), 181-206.

Clough, M. P. (1994). Diminish students' resistance to biological evolution. *The American Biology Teacher*, *86*(7), 409-415.

Dager, Z. R., & BouJaoude, S. (1997). Scientific views and religious beliefs of college students: The case of biological evolution. *Journal of Research in Science Teaching*, *34*(5), 429-445.

Demastes, S. S., Good, R. G., & Peebles, P. (1995). Students' conceptual ecologies and the process of conceptual change in evolution. *Science Education*, *79*(6), 637-666.

Deniz, H., Donnelly, L. A., & Yilmaz, I. (2008). Exploring the factors related to acceptance of evolutionary theory among Turkish preservice biology teachers: Toward a more informative conceptual ecology for biological evolution. *Journal of Research in Science Teaching*, 45(4), 420-443.

Dobzhansky, T. (1973). Nothing in Biology makes any sense except in the light of evolution. *The American Biology Teacher*, *35*, 125-29.

Ha, N. & Cha, H. (2006). Analysis of mis-conceptualizations regarding evolution originating from TV animation and science books for children. *Journal of Korean Elementary Science Education*, *25*(4), 352-362.

Ha, M., Haury, D. L., & Nehm, R. H. (2012). Feeling of certainty: Uncovering a missing link between knowledge and acceptance of evolution. *Journal of Research in Science Teaching*, *49*(1), 95-121.

Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp.169-190). Mahwah, NJ: Lawrence

Erlbaum Associates.

Heo, Y. (2010). *The relationship between Christian belief and the concept of evolution*. Master's thesis, The Korea National University of Education.

Hofer, B. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology*, *225*, 378-405.

Hofer, B. K., Lam, C. F., & DeLisi, A. (2011). Understanding evolutionary theory. In R. S. Taylor & M. Ferrari (Eds), *Epistemology and Science Education: Understanding the evolution vs. intelligent design controversy* (pp.77-94). Madison, NY: Routledge.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of educational research*, *67*(1), 88-140.

Hokayem, H., & BouJaoude, S. (2008). College students' perceptions of the theory of evolution. *Journal of Research in Science Teaching*, 45(4), 395-419.

Im, E. H., Cho, J. I., & Hong, H. H. (2007). College Students' Views about Origins of Life and Evolution. *Journal of Science Education, 31*, 11-26.

Johnson, R. L., & Peebles, E. E. (1987). The role of scientific understanding in college: Student acceptance of evolution. *The American Biology Teacher*, *49*, 93-98.

Kardash, C. M., & Scholes, R. J. (1996). Effects of preexisting beliefs, epistemological beliefs, and need for cognition on interpretation of controversial issues. *Journal of Educational Psychology*, *88*(2), 260.

Kim, J., & Cha, H. (2014). Association analysis of variables affected for macroevolution conceptions of in-service and pre-service biology teachers. *Biology Education*, *42*(4), 428-438.

Kim, S. Y. (2014). High school students' understanding and acceptance of the theory of evolution, and nature of science: The comparison of Christian vs. Non-Christian. *Teacher Education Research*, *53*(2), 221-230.

Kim, S. Y. (2015). The relation of high school students' epistemological belief, acceptance of evolutionary theory and evolutionary knowledge. *Journal of the Korean Association for Science Education*, *35*(2), 259-265.

Kim, S. Y., & Nehm, R. H. (2011). A cross-cultural comparison of Korean and American science teachers' views of evolution and the nature of science. *International Journal of Science Education*, 197-227.

Nehm, R. H., Kim, S. Y., & Sheppard, K. (2009). Academic preparation in biology and advocacy for teaching evolution: biology versus non-biology teachers. *Science Education*, *93*(6), 1122-1146.

Nehm, R. H., & Schonfeld, I. S. (2007). Does increasing biology teacher knowledge of evolution and the nature of science lead to greater preference for the teaching of evolution in schools? *Journal of Science Teacher Education*, *18*(5), 699-723.

Park, H. (2012). *Analysis of association among preservice biology teachers' acceptance and conception about evolution and their nature of science*. Master's thesis, The Korea National University of Education.

Rutledge, M. L., & Mitchell, M. A. (2002). High school biology teachers' knowledge structure, acceptance, and teaching of evolution. *The American Biology Teacher*, *64*, 21-27.

Rutledge, M. L., & Warden, M. A. (1999). Development and validation of the measure of acceptance of the theory of evolution instrument. *School Science and Mathematics*, *99*, 13-18.

Rutledge, M. L., & Warden, M. A. (2000). Science and high school biology teachers: Critical relationships. *The American Biology Teacher*, *62*, 23-31.

Scharmann, L. C. (1990). Enhancing an understanding of the premises of evolutionary theory: The influence of a diversified instructional strategy. *School Science and Mathematics*, *90*, 91-100.

Sinatra, G. M., Southerland, S. A., McConaughy, F., & Demastes, J. W. (2003). Intentions and beliefs in students' understanding and acceptance of biological evolution. *Journal of Research in Science Teaching*, *40*(5), 510-528.

Trani, R. (2004). I won't teach evolution: It's against my religion. *The American Biology Teacher*, *66*, 419-427.

Tsai, C., & Liu, S. (2005). Developing a multi-dimensional instrument for assessing students' epistemological views toward science. *International Journal of Science Education*, *27*(13), 1621-1638.