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Research Article

Missing link uncovered: Filipino high school students' knowledge of evolution predicts their evolution acceptance

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ABSTRACT

Evolution is a scientific theory of life. Literature shows no reports on Filipino high school students' level of evolution acceptance and its association with knowledge. This study examined the relationship between knowledge of evolution, and evolution acceptance among high school students in the Philippines. An explanatory sequential mixed methods design was used that involved the collection of quantitative data followed by in-depth qualitative interviews. This study found that despite having completed a specialized biology course in senior high school, students had 'low knowledge' of evolution, which can be attributed to distance learning, where teacher-student interactions were limited, and students managed their own learning. Also, the students were found to have 'moderate acceptance of evolution'. A moderately positive correlation was reported between knowledge and acceptance. Moreover, data shows that knowledge is a predictor of evolution acceptance. Thus, evolution should be given more emphasis in curriculum and teachers should engage students in meaningful learning experiences to dispel misconceptions of evolution in designing instruction to increase evolution acceptance progressively.

Keywords: knowledge, evolution acceptance, mixed methods, Philippines

INTRODUCTION

Evolution is a unifying theory of biology as it provides a scientific understanding of the history of life; however, a number of Filipino high students tend to overreact, negate, and question the validity of the evolutionary theory. This objection can influence students' willingness to investigate a scientific understanding of evolution and teachers' willingness to provide sound instruction on the concept (Bertka et al., 2019).

Studies have examined students' understanding of evolution and how they relate to their evolution acceptance. According to Mead et al. (2018), students with low acceptance of evolution prior to teaching are less receptive to evolution teaching. Studies suggest that students with more knowledge about evolution are more likely to accept the concept of evolution. The students' low level of understanding of evolution resulting from poorly crafted science curriculum, ineffective teaching strategies, teacher's low mastery of the subject matter, and teacher's religious bias may also lead to low evolution acceptance. Therefore, the conceptual ecology of the learner must be studied before the teaching strategy is organized and applied (Demastes et al., 1995). Some authors see students' epistemological beliefs, parent attitudes, and religiosity as potential predictors of evolution acceptance (Barnes et al., 2021; Borgerding et al., 2017).

Many reasons have been attributed to explain the low acceptance of evolutionary theory among students; however, there is only a limited number of recent literatures on evolutionary theory that can be found in the Philippines. One of the reasons is concerning content and pedagogy, the curriculum continues to be insufficient and unclear (Partosa, 2018). Using an explanatory sequential mixed methods design, this study examined the relationship between knowledge of evolution and evolution acceptance among high school science, technology, engineering, and mathematics (STEM) students in the Philippines. Furthermore, his study aimed to provide evidence on the relationship between knowledge and acceptance of evolution as a basis to craft an efficient, interdisciplinary, content-based, culture-sensitive, and learner-centered instructional design in evolution education for Filipino students.

Evolution is one of the most controversial sciences (Barnes & Brownell, 2017). In the Philippines, the secondary science education curriculum has been reformed to provide more significant opportunities for students to realize that principles studied inside the classroom are relevant to everyday life (Tan, 1988). The K to 12 program implemented under republic act 10533 or the enhanced basic education of 2013 provided

several innovations to improve the science curriculum such as new arrangement of competencies, learning pedagogies, mode of instruction, and integration of each branch of science in every grade level (Montebon, 2015). The science curriculum in every grade level envisions the development of scientifically, technologically, and environmentally literate and productive members of society. Students must possess effective communication, interpersonal and life-long learning skills, and scientific values and attitudes. These skills will be acquired through a curriculum that focuses on knowledge relevant to the real world and encompasses methods of inquiry. These will be implemented in a learning environment that promotes the construction of ideas and instils respect for others (SEI-DOST & UP NISMED, 2011).

STEM academic track for senior high school is designed to produce secondary school graduates who will take science, research, mathematics, and engineering-related courses at the university level, thereby contributing to the country's scientific and scholarly workforce (National Research Council, 2014). Senior high school STEM students are required to take specialized general biology 1 and general biology 2 courses in grade 11 and grade 12. General biology 1 course is designed to enhance understanding of the principles and concepts in studying biology, particularly life processes at the cellular and molecular levels. It also covers the transformation of energy in organisms. The topics on evolution and the origin of biodiversity relevance, mechanisms, evidence or bases, and theories of evolution are part of general biology 2 course. The course is designed to enhance the understanding of the principles and concepts in the study of biology, particularly heredity and variation, and the diversity of living organisms, their structure, function, and evolution (Department of Education, 2016).

Studies have been conducted over the last two decades to assess evolution acceptance. In 2005, a cross-national study of evolution acceptance was undertaken in 34 nations worldwide (excluding the Philippines). The concept of evolution was accepted by 80.00% or more of adults in Denmark, France, Iceland, and Sweden as well as 78.00% of adults in Japan. Furthermore, Japan and 32 European countries have higher evolution acceptance than American adults (Miller et al., 2006).

In a recent study, most Americans rejected some or all the evolutionary theory (Weisberg et al., 2018). In China, the acceptance level for the general Chinese public is 66.70%, with 88.00% of Chinese respondents accepting naturalistic evolution (Zhang et al., 2022). Indonesians also reported greater acceptance of microevolution, followed by lower acceptance of macroevolution and human evolution (Rachmatullah et al., 2018).

Based on the limited data of studies on evolution education in the Philippines, a study conducted by Clores and Limjap (2006) showed that 23 out of 37, or 62.16%, Filipino students interviewed accepted evolution. However, nine students, or 24.32%, expressed rejection of the theory. The authors conclude that students' current worldviews, in the form of attitudes and beliefs, affect how they understand evolution. Aberilla et al. (2021) explored the overall acceptance of evolution among undergraduate students in a state university in the Philippines. Both groups, STEM, and non-STEM college students, possess moderate evolution acceptance. The study sees a need to develop a STEM-based instructional design emphasized in the science curriculum. A teaching design would fill in the gaps in understanding concepts of evolution and its significance in advancing science, medical technology (understanding diseases and its cure), and academic society.

Knowledge of evolution is perhaps the most intuitive construct related to evolution acceptance (Dunk et al., 2017). A comparative study on acceptance and knowledge of evolution in China and the United States found that individuals who accept evolution have a much higher mean score on the knowledge measure than those who do not (Zhang et al., 2022). The Chinese sample had considerably higher evolution acceptance than the United States but no significant difference in their average levels of evolution knowledge.

Interestingly, results from various studies emphasize a strong positive relationship between evolution acceptance and knowledge (Heddy et al., 2013). Evolution knowledge was shown to be significantly correlated with acceptance among high school science teachers (Rutledge & Warden, 2000). Deniz et al. (2008) also found a significant correlation between knowledge of evolution and acceptance. This indicates that students with more knowledge about evolution are more likely to accept evolution. Also, Gefaell et al. (2020) assessed students' level of evolution acceptance and knowledge at various Spanish universities. The students exhibit a moderate understanding of evolution but a high level of acceptance of evolution. On the other hand, contradicting findings were observed by Sinatra et al. (2003) that there was no relationship between evolution acceptance and knowledge. However, epistemological views and cognitive dispositions were related to evolution acceptance.

MATERIALS & METHODS

This study employed an explanatory sequential mixed methods design involving two distinct data-collection phases. The first phase involved collecting and analysing quantitative data such as student demographics, knowledge of evolution, and evolution acceptance. To further explain the quantitative findings, a subsequent qualitative phase through interviews was designed to explain the initial quantitative data. This design intended to use qualitative data to explain the quantitative results further.

Instrument

The survey questionnaire used in this study included questions on the respondents' sex. The knowledge of evolution exam (KEE) developed by Moore et al. (2009) is a simple 10-item test with five options per item designed to measure the knowledge of basic concepts of evolutionary theory such as fitness, natural selection, and evidence for evolution among high school students. Students' scores are expressed in percentages. A self-made score interpretation matrix of their knowledge test score was categorized as low (zero-four), moderate (five-eight), and high (nine-12).

The measure of acceptance of the theory of evolution (MATE) developed by Rutledge and Warden (1999) was used to

assess students' level of evolution acceptance. It is a standardized 20-item Likert scale designed to measure overall acceptance of evolutionary theory by assessing their perceptions of its scientific validity, ability to explain phenomena, and acceptance within the scientific community (Rutledge & Warden, 1999). MATE has been the most frequently used test (Barnes et al., 2019; Gefaell et al., 2020; Rissler et al., 2013; Romine et al., 2017). Categories of evolution acceptance are very high acceptance: 89-100, high acceptance: 77-88, moderate acceptance: 65-76, low acceptance: 53-64, and very low acceptance: 20-52. In several studies, KEE and MATE had been chosen together as a practical combination in data collection (Gefaell et al., 2020; Moore et al., 2011; Rice et al., 2015; Rissler et al., 2014). All three instruments were pilot tested with Cronbach's alpha levels of reliability.

The in-depth qualitative interviews used an interview protocol containing five open-ended questions about evolution knowledge, religiosity, and evolution acceptance adapted from Woods and Scharmann (2001) to further explain quantitative findings.

Sampling

This study employed an explanatory sequential mixed methods design involving collecting quantitative data followed by in-depth qualitative interviews. Cluster sampling was conducted during the quantitative phase of data collection in which clusters were initially identified (schools offering STEM programs for senior high school) and then randomly selected a cluster and studied the students within the cluster (school). The sample size was determined using a margin of error of 5.00% and a confidence interval (CI) of 95%. The minimum sample size estimated for the study was 216. A sample size of 227 STEM students agreed to participate in the study.

The qualitative phase of the data collection employed representative sampling. The recruitment of five students for qualitative interviews was carried out by randomly selecting one student from five categories of evolution acceptance based on the actual quantitative results to understand how groups differ and further explain quantitative data (Creswell & Clark, 2011).

Data Collection

An approved ethics review was obtained from the university research ethics committee. A written permit to conduct study in the identified schools was also acquired from the division superintendent. The respondents were asked to sign the informed consent provided by the researcher prior to data gathering. The online survey forms were sent to the students through via messenger groups and were given ample time to accomplish the survey. Upon collecting the required data, the quantitative results were consolidated and statistically analysed. After the analysis of quantitative results, five students were recruited for an online individual qualitative interview via recorded zoom meetings using an interview protocol. Interview responses were process using the six-phase guide on thematic analysis by Braun and Clarke (2006).

Table 1. Level of knowledge, religiosity, and evolution acceptance (n=227)

	Mean	SD	Descriptor
Knowledge of evolution (KEE)	4.52	1.53	Low knowledge
Evolution acceptance (MATE)	67.90	8.98	Moderate acceptance

Note: KEE: low (0-4), moderate (5–8), and high (9-12); MATE: very high acceptance: 89-100, high acceptance: 77-88, moderate acceptance: 65-76, low acceptance: 53-64, and very low acceptance: 20-52.

Data Analysis

The data analysis in the explanatory sequential design occurs in three phases: the analysis of the initial quantitative data, an analysis of the follow-up qualitative data, and an analysis of how the qualitative data helps to explain the quantitative data to answer the mixed methods question (Creswell & Clark, 2017).

For the quantitative phase of this study, frequencies, weighted means, and standard deviations were calculated for the levels of knowledge, and evolution acceptance. Moreover, the Pearson product moment of correlation was used to determine if there is a significant relationship between the students' level of evolution acceptance and their knowledge using Microsoft Excel. A linear regression analysis is an extension of correlational analysis that describes the relationship between a dependent variable (acceptance) and independent variable (knowledge).

For the qualitative phase, responses were analysed using the six-phase guide on thematic analysis by Braun and Clarke (2006). The thematic analysis begins with becoming familiar with the data, generate initial codes, search for themes, review themes, define themes, and make a write-up.

The integration of quantitative and qualitative data was analysed through a sequential integration approach (Morse & Niehaus, 2009) to answer the mixed-method question. Qualitative data from interviews will further explain the statistical data on evolution acceptance. A statistics-by-theme joint display was created to make a specific link between the two data sources and to help visualize how the qualitative themes and codes provide a deeper understanding of the statistical findings (Guetterman et al., 2015).

RESULTS & DISCUSSION

Levels of Evolution Knowledge, & Evolution Acceptance

Table 1 summarizes the levels of evolution knowledge, and evolution acceptance of STEM students. Among the 227 respondents, 86 (38.00%) were males, and 141 (62.00%) were females. There were 207 (91%) students with religion, 72 males and 135 females, respectively. Moreover, there were 20 students (14 males and six females) reported with no religion. The mean score of correctly answered evolution questions in the knowledge test was 4.52 (±1.53), interpreted as 'low knowledge' (**Table 1**). Although students' scores on individual questions varied greatly, the mean scores on all questions were low. The students' low knowledge of evolution may be due to the distance learning mode adopted by the Department of

Table 2. Correlation and simple linear regression between knowledge, and evolution acceptance (n=227)

	R	R^2	Adjusted R^2
Knowledge of evolution	0.4281*	0.8133	0.1796

Note: Dependent variable: Evolution acceptance; *Correlation is significant at the 0.01 level

Education (2021) during the pandemic. These students were in full modular distance learning in which topics in biology were streamlined to the most essential topics. In modular learning, teacher-student interactions were also limited resulting to inadequate discussions of the lessons.

The results of this study corroborated the findings, which stated that Brazilian (Tavares & Bobrowsky, 2018) and American high school students (Moore et al., 2011) have low knowledge of evolution because of a lack of emphasis of evolutionary concepts in science curriculum. The findings of this study, on the other hand, contradicted the study, which found that science undergraduate students have moderate knowledge of evolution due to the relative weight of evolutionary themes within the curriculum, implying that increasing the number of hours dedicated to this topic could have a direct influence on students' knowledge of it (Gefaell et al., 2020). Though the respondents of this study were STEM students and have taken biology in their junior high school, the results connote that lessons on evolution may not have been thoroughly discussed in the specialized biology course in grade 12.

The student's average score on MATE, as seen in **Table 1**, is 67.90 (±8.98), which means moderate acceptance. The students' moderate acceptance of evolution can be attributed to low knowledge of evolution and their religiosity. This result supported the studies that mentioned that undergraduate students in a science program moderately accept evolution, due to evolution misconceptions, influence of teaching pedagogies, socio-cultural factors, views of the compatibility of evolution and religion, and appreciation of the nature of science (Aberilla et al., 2021; Athanasiou & Papadopoulou, 2012; Borgerding et al., 2016).

Relationship Between Levels of Knowledge of Evolution, & Evolution Acceptance

The correlation between the levels of knowledge of evolution, and evolution acceptance are presented in **Table 2**. A Pearson's *r* data analysis on knowledge and evolution acceptance revealed a significant moderate positive correlation, r=0.4281, p<0.01 (**Table 2**). This data indicates that the Pearson's *r* result rejects the null hypothesis; hence, knowledge of evolution is positively associated to evolution acceptance. Also, **Table 2** presents R-value, which is one measure of the quality of the dependent variable prediction and is equal to 0.8133, indicating a good level of prediction. Thus, this study implies that Filipino students with more knowledge about evolution are more likely to accept evolution. In this study, the students have a low level of knowledge of evolution can be the result of distance learning implemented during the pandemic, wherein discussion of evolution concepts and teacher-student interactions were limited. This can explain why the students have moderate acceptance of evolution despite taking a specialized biology course in senior high school. The result of this study supported the previous findings, which found a positive correlation between knowledge and evolution acceptance (Deniz et al., 2008; Heddy et al., 2013; Tavares & Bobrowsky, 2018) among Chinese (Zhang et al., 2022), Brazilian (Gefaell et al., 2020), and American (Heddy et al., 2013) students.

Students Views on Relationship Between Knowledge to Their Evolution Acceptance

The quantitative data analysis phase has reported the relationship between knowledge of evolution and religiosity to acceptance of evolution. This section presents the results of the interview conducted to explain the prior quantitative data. An in-depth interview was conducted among five students of various levels of evolution acceptance.

The students were asked what they know about evolution. The response of the interview indicates a lack of understanding of evolution or difficulty learning it. They also admitted that their knowledge on the theory is superficial.

Table 3. Statistics-by-theme joint display for knowledge of evolution, and evolution acceptance

Quantitative Results	Qualitative Findings and Quotes	Mixed-Method Inference
Low knowledge of evolution	Poor knowledge of evolution "Yes, I already studied about evolution but not really deep or comprehensive because it was in modular distance learning." (Student 76)	Due to modular distance learning, STEM students still have poor knowledge of evolution despite completing a specialized biology course in senior high school.
Moderate acceptance of evolution	Acceptance of evolution based on personal beliefs "And with evolution, of course, there are loopholes. It's not perfect. It's actually kind of hard to decide which one. However, science is a discovery of facts and truth. I would lean more toward science, although I do not fully believe in the theory of evolution. I would only believe some parts of it, but not totally the whole of it." (Student 60)	Students believe that science is based on empirical evidence and natural laws; however, they also acknowledge that evolution as a theory has gaps and limitations.
Knowledge is positively correlated with evolution acceptance	Poor knowledge of evolution "I just don't believe that humans would have the same ancestors as some reptiles. Okay, since if we came from the same planet in the same environment, why would we have different traits? Why would mammals and the others would remain as reptiles?" (Student 60)	It is simple to refute evolution when a learner's knowledge of evolution is poor and influenced by misconceptions about its occurrence.

> "Yes, if we are talking about human evolution, I have something to share but not sufficient enough to answer questions related to it" (student 133).

> "Yes, I already studied about evolution but not really deep or comprehensive because it was in modular distance learning" (student 76).

> "Yes, but I had difficulty in online learning and self-study" (student 60).

> "Yes, but not very knowledgeable about it" (student 78 & student 14).

The concepts related to evolution are already covered in the K to 12 science framework of the Philippines, both in junior and senior high school. For students taking STEM program, a specialized course is offered in senior high school to strengthen their competence in evolution. However, due to distance learning, students presented difficulties in self-directed learning that affected the entire learning process. The learning competencies were streamlined to most essential learning competencies (MELCS) to adapt to modular distance learning (Department of Education, 2021) and the students were mostly left on their own to learn the lesson using the self-learning modules. Students can only ask questions using online applications such as messenger group chats and email. This may be why the students have low knowledge of evolution (see **Table 1**).

Some of the students also moderately accept or reject evolution based on misconceptions of human evolution either because of poor knowledge of evolution reinforced by religious beliefs:

> "I do not believe humans would have the same ancestors as some reptiles. Okay, since if we came from the same planet in the same environment, why would we have different traits? Why would mammals and the others would remain as reptiles?" (student 60).

The misconception of the student quoted above on how evolution takes place makes it easy to negate the evolution concept. Moreover, student 60 failed to understand that it is the population that evolves, not the species, that produces novel traits and altered genes, leading to speciation.

Another student indicated hesitance on the acceptance on the origin of species:

> "Basically, if we originated from apes, therefore, they were the first organisms who lived on earth before humans. There is a big difference in the belief of science because God never lies. One thing God cannot do, He cannot lie. therefore, what is written in the Bible (Genesis 1:26-27; 2:7), it is perfect, true, exact" (student 133).

Charles Darwin's origin of species struggled to align deep-rooted religious beliefs with his ideas based on natural law. He defined evolution as "descent with modification," the idea that species change over time, give rise to new species, and share a common ancestor (Darwin, 1909). Student 133 was misinformed about the existence of organisms and the origin of species. This view demonstrates how strongly held religious beliefs can influence a learner's understanding of evolution, leading to scientific misconceptions. Also, the concepts of 'common descent' and 'process of change' came up frequently in students' definitions of evolution. This is clear from the responses given by every student, which were based on "common ancestor" and "man evolved from apes." Student 60 mentioned, "Evolution is a change or adaptation for survival that happens over time. Humans came from a single ancestor". Student 14 also added, "evolution is the theory of Charles Darwin that man is the evolution of ape."

The qualitative data explained the initial quantitative findings of this study. It is found out that students' perceptions of evolution are mainly contributed by a variety of factors namely, knowledge of evolution, learning delivery and instruction, misconceptions that influence their acceptance of evolution.

Integration of Quantitative & Qualitative Data on Knowledge of Evolution, & Evolution Acceptance

Table 3 presents a statistics-by-theme joint display that summarizes the integration between the levels of evolution knowledge, and evolution acceptance of STEM students.

Pedagogical implications

The low scores obtained by STEM students in this study can be explained by the lack of emphasis given to evolution in the curriculum, misconceptions of evolution concepts and the learning delivery mode in the time of the pandemic. The concepts related to evolution is covered in the K to 12 science framework. Evolution is taught in junior high school in terms of natural selection as its process, mutations as sources of variation, speciation, environmental stresses, and biodiversity (Partosa, 2018). The advanced biology course (general biology 2) taken by STEM students aims to provide better understanding of genetics, variation, and the diversity of living organisms and their structure, function, and evolution (Department of Education, 2016). However, the grade 12 STEM students who took the general biology course in the first semester of the school year 2021-2022 were in full distance learning mode, wherein the science lessons were streamlined into MELCS creating a shortened and simplified version of the science curriculum (Department of Education, 2021). This has affected the quality of science instruction evident in this study. STEM students who participated in this study showed that despite taking biology courses in junior and senior high school, the data on knowledge of evolution may also imply lack of emphasis on the topic in the science curriculum and the quality of science instruction.

Misconceptions of evolution also posed a challenge to evolution acceptance. It is simple to refute evolution when a learner's knowledge of evolution is poor and reinforced by misconceptions about how it occurs. This study found that knowledge is a predictor of evolution acceptance. Hence, there is a need to design instruction that elicits prior knowledge and explores evidence that conflicts with their current perspective (Clores & Limap, 2006) to address the problem in low understanding of evolution. These misconceptions can be

attributed from direct experience, self-constructed misconception, taught-and-learned misconception from parents and society, and religion (Alters & Nelson, 2002).

When understanding the goal of science instruction, is it vital to consider evolution's acceptance in evolution education? The findings of this study support the notion that learning evolution is not a "cognitive-only" process but rather a process involving relevant constructs of the conceptual ecology of biological evolution: the cognitive (knowledge of evolution), affective, and contextual domains.

Students should understand that science explains the natural phenomena and supported by pieces of evidence through a scientific method. A meaningful and respectful intellectual discourse among students should be highlighted. Activities like journal analysis of some research in evolutionary biology, watching of science documentaries, and film-showing can provide a picture to the students of what science has to say about the origin of mankind and eliminate its common misconceptions. Students should comprehend the importance of evolutionary biology as one of the core themes of life sciences. Laats and Siegel (2021) suggested a key to accommodate both viewpoints, is to disentangle from knowledge. A student does not need to believe in evolution to understand its tenets and evidence, and in this way, students can fully be literate in modern scientific thought and still maintain contrary religious and cultural views.

Finally, inside the classroom, students should have a broader understanding that people do have a varied range of beliefs. Teachers should not attempt to change the religious beliefs of the students and fully accept science, instead bridge the gaps between the two, increase student engagement and active participation in evolution discussion, decrease perceived conflict, and minimize misconceptions in biology classes. Thus, teachers should be objective facilitators of learning in teaching evolution acknowledging students' prior conceptions of evolution, addressing preconceived notions and misconceptions, and considering personal beliefs and religious beliefs in designing instruction to ease the perceived conflict between science and religion, therefore progressively increasing acceptance of evolution.

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Availability of data: All data generated or analyzed during this study are available for sharing upon request. Interested parties are encouraged to direct their inquiries to the author, who will facilitate the provision of the data in a timely and appropriate manner.

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