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Pre-service biology teachers' acceptance of evolutionary theory and their preference for its teaching

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Abstract

Background: Fostering pre-service teachers' acceptance of evolutionary theory and their preference for its teaching implies knowledge of the factors which influence both constructs. This study aims to explore how cognitive (knowledge of evolution), affective (attitude towards religion and science, scientism, and creationism), and contextual factors (age, gender, parents' educational qualification, semester, teacher education program) are related to acceptance and preference. Furthermore, the study aims at exploring the relationship between acceptance and preference.

Methods: A total of 180 German pre-service biology teachers participated in the study.

Results: Our regression analysis reveals that the acceptance of evolutionary theory is significantly related to creationism, the attitude towards science, the knowledge of evolution, gender, and the pre-service teachers' semester. Furthermore, the regression analysis shows that a preference for teaching evolution is significantly related to creationism, the knowledge of evolution, and also gender. Interestingly, after controlling for these variables, the attitude towards religion is not significantly related to either the acceptance of evolutionary theory or the preference for teaching evolution. Finally, the regression analysis shows that acceptance and preference are weakly, but significantly related.

Conclusions: For teacher education, these results point out that religiosity should not be considered a barrier to acceptance and preference in principle. Moreover, fostering a profound knowledge of evolution could be one way to improve teaching practices.

Keywords: Acceptance of evolutionary theory; Preference for teaching evolution; Predictors; Pre-service biology teachers

Despite the clear position of the scientific community – it considers evolutionary theory one of the most important achievements in modern biology – there are several reasons why evolutionary theory and its teaching in schools constitute a controversial issue in many countries (e.g., evolutionary theory is believed to contradict religious beliefs). Miller et al. (2006) report considerable cultural differences in the public acceptance of human evolution, with a minimum level of acceptance in the USA and Turkey as well as a maximum level in the Scandinavian countries. Although the level of acceptance in Middle and Western Europe is generally higher than in the US and Turkey, creationist beliefs have been observed in Europe as well (e.g., Curry 2009). Graf and Soran (2011) report that German pre-service biology teachers do not exhibit the desired acceptance of evolutionary theory either.

Especially in the US, science teachers are considered a 'missing link' between scientists' understanding of evolution and the public's ignorance of (or resistance to) evolutionary theory (Nehm and Schonfeld 2007). Among other things, this might be caused by the fact that curricular standards for the teaching of evolution vary considerably between states (Lerner et al. 2012). In Missouri, for example, all controversial evolution contents are regarded as optional for teaching so that they will not be assessed. Tennessee, as another example, relegates evolution to an elective high school course. Consequently, some students learn evolutionary theory others do not. Other states (e.g., Colorado, Montana) feed doubts of evolution by explicitly

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teaching the strengths and weaknesses of evolutionary theory which might pave the way for creationism or intelligent design (Lerner et al. 2012). Finally, most states' standards neglect human evolution which "marks a subtle but important victory for creationists" (Lerner et al. 2012, p. 10). Thus, it is no surprise that in the case of many science and biology teachers, the preference for teaching evolution is very low. This becomes apparent when teachers try to avoid controversy in the classroom by either omitting evolutionary theory or by teaching unscientific alternatives such as creationism or intelligent design (Berkman and Plutzer 2011). Unfortunately, these teaching practices have been shown to increase the acceptance of creationism as a scientific theory by high school students (Moore and Cotner 2009).

Unlike in the United States, evolutionary theory is mandatory both in junior and senior high schools in Germany. Thus, German biology teachers do not have a choice between teaching evolution and unscientific creationist alternatives. Nevertheless, even experienced biology teacher trainers have expressed concerns about the epistemological status of evolutionary theory (van Dijk 2009). Accordingly, creationism in the classroom is reported repeatedly even in Germany (e.g., Kamann 2013).

Current reviews (e.g., Allmon 2011; Smith 2010) have summarized a variety of factors which are related to the acceptance of evolutionary theory. Interestingly, studies on the preference for teaching evolution name similar factors. Thus, our study aims to analyze how a set of cognitive (e.g., knowledge of evolution), affective (e.g., attitude towards religion), and contextual factors (e.g., educational background) is related to the acceptance of evolutionary theory and the preference for teaching evolution. As we expect acceptance to influence preference, our study additionally aims to scrutinize the relationship between acceptance and preference.

Background

Conceptual ecology has been used as a theoretical framework to describe the influence of particular factors on the acceptance of evolutionary theory. In the following, we will clarify the model of conceptual ecology in the context of evolution, define the acceptance of evolutionary theory and the preference for teaching evolution, give reasons for the intention to teach both evolutionary theory and unscientific alternatives as an indicator for preference, and provide a review of previous research.

Conceptual ecology as a framework for learning acceptance of evolutionary theory

The general idea of conceptual ecology traces back to the early stages of conceptual change theory (cf. Pintrich et al. 1993; Posner et al. 1982). Borrowing the idea from Toulmin (1972), Posner et al. (1982) used 'conceptual ecology' to describe all those concepts which govern a conceptual change process. In its initial form, conceptual ecology was largely restricted to the cognitive domain (including analogies, metaphors, and knowledge) as well as to epistemological commitments and metaphysical concepts. As one merit of the so-called 'warming trend' in conceptual change – largely influenced by Pintrich et al. (1993) – both affective and intentional level constructs such as epistemological beliefs, belief identification, and willingness to question one's beliefs were integrated into the idea (Sinatra et al. 2003).

In recent years, the idea of conceptual ecology has been applied to both the acceptance and the understanding of evolutionary theory by several authors (Athanasiou et al. 2012; Athanasiou and Papadopoulou 2012; Demastes et al. 1995; Deniz et al. 2008). Referring to Sinatra et al.'s (2003) extension of the classical conceptual change model known as intentional conceptual change, Deniz et al. (2008) particularized the idea of conceptual ecology for biological evolution by explicitly distinguishing between three different domains of factors: a cognitive, an affective, and a contextual domain.

In summary, conceptual ecology provides a conceptual framework which covers a variety of factors influencing the learning of evolutionary theory, and thus being relevant for both the acceptance of evolutionary theory and the preference for teaching evolution.

Factors influencing the acceptance of evolutionary theory

In addition to the central question of what factors influence the acceptance of evolutionary theory, the question about the meaning of acceptance and the underlying construct has previously attracted attention (cf. Konnemann et al. 2012; Smith 2010). Fully aware of the ongoing discussion about the underlying construct, the lack of a consensual definition, as well as the necessity for a scientific clarification of the acceptance of evolutionary theory (cf. Smith 2010), we decided to follow the approach by Rutledge and Warden (1999), which has been established in research. Accordingly, the overall acceptance of evolutionary theory is understood as "perceptions of evolutionary theory's scientific validity, ability to explain phenomena, and acceptance within the scientific community" (Rutledge and Warden 1999, pp. 13–14).

Even though only few studies within recent evolution education research directly refer to conceptual ecology as their theoretical framework, there are several studies which indirectly describe the conceptual ecology of biological evolution by modeling the influence of various factors on the acceptance of evolutionary theory. Applying the taxonomy of Deniz et al. (2008), Table 1 shows in how far cognitive, affective, and contextual domain factors were considered in previous studies.

As shown in Table 1, the majority of studies consider all three domains, while only few studies focus on one or two

Table 1 Studies investigating predictors for the acceptance of evolutionary theory ordered by explained variance

Explained variance	Study	Sample	Domains considered
7.2%	Akyol et al. 2010	Turkish pre-service science teachers (n = 136)	Cognitive
10.5%	Deniz et al. 2008	Turkish pre-service biology teachers (n = 132)	Cognitive, affective, contextual
13.0%	Sinatra et al. 2003	US-American undergraduate non-major biology students (n = 93)	Cognitive, affective
17.0%	Akyol et al. 2012	Turkish pre-service science teachers (n = 415)	Cognitive
18.0%	Miller et al. 2006	European adults (n = 13,587)	Cognitive, affective, contextual
19.7%	Graf and Soran 2011	Turkish pre-service biology teachers (n = 520)	Cognitive, affective
26.0%	Mazur 2004	US-American adults (n = 3,673)	Cognitive, affective, contextual
29.0%	Athanasiou and Papadopoulou 2012	Greek pre-service teachers in early childhood education (n = 350)	Cognitive, affective, contextual
33.0%	Ha et al. 2012	South Korean pre-service biology teachers (n = 124)	Cognitive, affective, contextual
40.2%	Graf and Soran 2011	German pre-service biology teachers (n = 1,228)	Cognitive, affective, contextual
42.0%	Losh and Nzekwe 2011	US American pre-service teachers (n = 663)	Cognitive, affective, contextual
44.2%	Athanasiou et al. 2012	Greek pre-service teachers in early childhood education (n = 320)	Cognitive, affective
45.0%	Mazur 2010	US-American adults (GSS sample, n > 1,600)	Cognitive, affective, contextual
46.0%	Miller et al. 2006	US-American adults (n = 2,066)	Cognitive, affective, contextual

domains. Interestingly, the models which do not consider the affective domain at all can be found among the least predictive models. However, the proportion of explained variance differs substantially even between the studies which consider all three domains. Reasons for this might for example be found in the cultural context and in the specific indicators of the three considered domains.

Cognitive factors related to acceptance

Within the cognitive domain, significant predictive effects were reported for the understanding of evolution (Akyol et al. 2012; Athanasiou et al. 2012; Deniz et al. 2008; Ha et al. 2012), for the understanding of NOS (Akyol et al. 2010, 2012; Athanasiou et al. 2012; Losh and Nzekwe 2011), and for genetic literacy (Miller et al. 2006). It is assumed that the effects of understanding evolution can be explained by the fact that a lack of understanding might act as a barrier to acceptance (Smith 2010, 527). However, the direction of the effect has been discussed ever since (Sinatra et al. 2003, 512). Moreover, it has been argued that a lack of acceptance can act as a barrier to understanding, which means that persons who reject evolutionary theory are unlikely to learn about evolution or may even actively choose not to learn about it (Smith 2010, 527). Similarly, numerous authors have argued for a key role of understanding the nature of science in order to accept evolutionary theory (e.g., Lombrozo et al. 2008; Sinatra et al. 2003; Smith and Scharmann 1999). For instance, Sinatra et al. (2003) state that it is important (1) to understand the differences between religious belief and scientific knowledge, (2) to be able to differentiate between science and pseudoscience, and (3) to understand the epistemological status of a theory in order to accept evolutionary theory. Finally, the documented positive effect of genetic literacy on the acceptance of evolutionary theory has been attributed to a general literacy effect. Since genetics and evolution both can be considered as core ideas of the 20^{th} and 21^{st} century biology, literacy in one of the two areas is treated as a general indicator for literacy (Miller et al. 2006). In contrast, no predictive effect was found for scientific knowledge unrelated to evolution (Mazur 2004).

Affective factors related to acceptance

Among the affective factors, four major groups of constructs have been investigated so far: (1) attitude towards religion (religiosity, religious beliefs; Athanasiou et al. 2012; Graf and Soran 2011; Losh and Nzekwe 2011; Mazur 2004, 2010; Miller et al. 2006), (2) attitude towards science (Graf and Soran 2011; Miller et al. 2006), (3) intentional level constructs (epistemological beliefs, thinking dispositions; Athanasiou and Papadopoulou 2012; Athanasiou et al. 2012; Deniz et al. 2008; Sinatra et al. 2003), and (4) others (e.g., attitude towards life (Miller et al. 2006); feeling of certainty (Ha et al. 2012)). Interestingly, the attitude towards religion and the attitude towards science were revealed to be important predictors every time they were considered, while the intentional level constructs only showed small (thinking dispositions: Athanasiou et al. 2012; Athanasiou and Papadopoulou 2012; Deniz et al. 2008) or no predictive effects (epistemological beliefs: Deniz et al. 2008; Sinatra et al. 2003).

Further affective constructs which might play a role in this context are creationist and scientistic attitudes or beliefs (abbreviated creationism and scientism). Following the definitions by Astley and Francis (2010), creationism reflects the "rejection of evolution and common descent as an account of the development of living things, in favour of a belief in God's special and independent creation of every form of life" (p. 5). Although the acceptance of evolutionary theory and creationism represent similar concepts which might at first sight appear to be two sides of the same coin, both constructs (creationism and acceptance) are theoretically different. The main difference is that creation is irrelevant for the acceptance of evolutionary theory, whereas creationism emphasizes the "idea of creation by a supernatural force" (Scott 2009). In contrast, scientism takes the view that absolute truth may be obtained by science, and only by science (Astley and Francis 2010), which is inconsistent with the nature of science (Lederman and Abd-El-Khalick 1998). While effects of both attitudes towards science and attitudes towards religion on the acceptance of evolution have been documented repeatedly, neither the effects of creationist nor scientistic beliefs have been discussed explicitly.

Contextual factors related to acceptance

With regard to the personal background of the participants, age (Mazur 2004; Miller et al. 2006), gender (Losh and Nzekwe 2011; Miller et al. 2006), religious affiliation (Ha et al. 2012; Losh and Nzekwe 2011), and political views (Mazur 2004, 2010; Miller et al. 2006) have been identified as useful predictors. No predictive effects were found for race, region, and urbanization (Mazur 2004). Concerning the participants' educational background, the level of education (i.e., highest school degree or years of education; Ha et al. 2012; Mazur 2004, 2010; Miller et al. 2006), the parents' educational level (Deniz et al. 2008), and disciplinary major (Losh and Nzekwe 2011) proved to be predictive, while neither the years spent in the biology education program (Deniz et al. 2008) nor the grade point average (Losh and Nzekwe 2011) showed significant predictiveness.

Factors influencing the preference for teaching evolution

It has been shown that both the acceptance of evolutionary theory and teaching practices are highly dependent on the cultural context (e.g., Hermann 2013; Miller et al. 2006). In the US, Moore (2007) reports that almost 25% of the students who attend public schools were taught creationism either exclusively or as an alternative to evolutionary theory. Another 21% were even taught neither evolution nor creationism. Nehm and Schonfeld (2007) state that the reason for this practice supposedly is a missing preference for teaching evolution, which is defined as the tendency to teach evolution as an alternative to creationism. According to Nehm and Schonfeld (2007), three specifications of the preference for teaching evolution can be distinguished: (1) teaching evolutionary theory or (2) unscientific alternatives (e.g., creationism or Intelligent Design) exclusively, and (3) teaching both evolutionary theory and unscientific alternatives. In Germany, the omission of evolutionary theory in the science classroom might be the exception rather than the rule; this is due to authoritative curriculum standards which dictate evolutionary theory as mandatory. Nevertheless, reports about creationism in the German classroom repeatedly appear in the media (e.g., Bönisch 2010; Kamann 2013; Mersch 2006). They reached a temporary peak in 2007, when the former Hessian minister of education, Karin Wolff, suggested including the biblical account of creation in the biology curriculum. As German teachers are bound to teach evolutionary theory, it does not really make sense to exclusively determine their preference for teaching evolution or unscientific alternatives in the same fashion as in the US (e.g., Nehm and Schonfeld 2007). In contrast, it is of particular interest whether German teachers intend to teach both evolutionary theory and unscientific alternatives. In the following, we will consequently investigate the intention to teach both evolutionary theory and unscientific alternatives as a culturally-adapted indicator for the preference for teaching evolution.

In a similar fashion as with the acceptance of evolutionary theory, factors of the cognitive, affective, and contextual domains might influence the intention to teach both evolutionary theory and unscientific alternatives in particular and the preference for teaching evolution in general.

Cognitive factors related to preference

Studying the preference for teaching evolution in US-American pre-service secondary biology teachers, Nehm and Schonfeld (2007) found that pre-service teachers who preferred that students are exclusively taught evolutionary theory significantly outperformed those colleagues who preferred to teach evolution as well as creationism both in a conceptual knowledge test (ECK) and a test on the understanding of the nature of science (ENOS; both related to evolutionary theory). However, in a later study, Nehm et al. (2009) observed a weak relationship between knowledge variables (e.g., ECK, ENOS) and the preference for teaching evolution in pre-service biology and non-biology teachers. Furthermore, they found that attending an evolution course does not decrease the preference for teaching creationism. Finally, insufficient content knowledge (e.g., Griffith and Brem 2004; Nadelson and Nadelson 2010) and a lack of pedagogical content knowledge (Asghar et al. 2007; Sanders and Ngxola 2009) have been shown to contribute to a low preference for teaching evolution.

Affective factors related to preference

An important affective factor which results in the omission of evolutionary theory in school science is supposed to be the religiosity of teachers (e.g., Goldston and Kyzer 2009; Sanders and Ngxola 2009). In a qualitative study with Lebanese secondary school biology teachers, BouJaoude et al. (2011) found that those teachers who rejected evolutionary theory for religious reasons restricted its teaching. They either objected to the teaching of evolution, stated that evolution and creationism should be given equal time, or held the view that students should be allowed to take their own stand. Similar results were found by Trani (2004) for the US (high school biology teachers) and Asghar et al. (2007) for Canada (pre-service elementary teachers).

Contextual factors related to preference

Three contextual domain factors which influence the preference for teaching evolution are proposed by Moore (2007): (1) potential conflicts with students, parents, and members of the public, (2) a lack of support or even negative repercussions from school administrators, and (3) a misunderstanding of the laws related to the teaching of evolution. More specifically, there are studies indicating that social concerns (e.g., the individuals' perception of their role within social groups and their recognition of sociocultural forces) can influence the decision to teach evolution or not (Balgopal 2014; Goldston and Kyzer 2009; Shanaham and Nieswandt 2011). Other studies indicate that teachers', especially pre-service or novice teachers', decision to teach evolution depends on factors such as job security and administrative support (Griffith and Brem 2004; Long 2012).

The relation between acceptance and preference

Our review of the research shows that factors from all three domains have an influence on both the acceptance of and the preference for teaching evolution. Particularly, the understanding of evolution and religiosity are discussed as important predictors for both acceptance of evolution and the preference for its teaching. Furthermore, several studies have shown that teachers' acceptance of evolutionary theory is related to their instructional approaches. For example, those teachers who accept evolution place more emphasis on the topic (e.g., Aguillard 1999); this indicates that acceptance itself has an influence on the preference for teaching evolution.

Research questions

In this study, we aim to examine the relationship between a particular set of factors (cognitive, affective, and contextual ones) and the acceptance of evolution as well as the 'intention to teach both evolutionary theory and unscientific alternatives' (see Figure 1) as a culturally-adapted indicator for the preference for teaching evolution in the German context. Furthermore, we aim to investigate the relationship between acceptance and intention.

Our research is guided by three research questions.

1. To what extent are the selected cognitive, affective, and contextual factors (cf. Figure 1) related to the acceptance of evolutionary theory?
2. To what extent are the selected cognitive, affective, and contextual factors (cf. Figure 1) related to the intention to teach both evolutionary theory and unscientific alternatives?
3. To what extent is the acceptance of evolutionary theory related to the intention to teach both evolutionary theory and unscientific alternatives?

Methods

Sample and design

A total of 180 German pre-service biology teachers participated in our study. All participants were ethnically caucasian and the majority was female (79%). The average age was 22.8 years (*SD* = 2.3). As evolutionary theory is mandatory both in junior and senior high schools in Germany, all participants should have been taught evolutionary theory in school (Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK] 2004a). In Germany, teacher education encompasses 3.5 to 5 years of higher education and puts emphasis on the development of professional knowledge (subject matter knowledge, pedagogical content knowledge, and pedagogical knowledge). Moreover, it includes instructional practice in schools (about 2 to 5 months altogether; Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK] 2013).

Pre-service secondary teachers choose between two teacher education programs, which are adapted to the requirements of the German school system. On the secondary level, there is a clear distinction between schools which qualify their students for an academic career (grade 5–12 [or 13]; academic track) and schools which qualify their students for a non-academic career (grade 5–9 [or 10]; non-academic track). Although both teacher education programs conclude with a teaching certificate for at least two subjects (e.g., biology and mathematics; Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK] 2013), academic-track pre-service teachers (65.1% of the sample) have to master higher subject matter knowledge demands (approximately one third more) than their non-academic-track colleagues (34.9% of the sample). Accordingly, the national standards for teacher education (Secretariat of

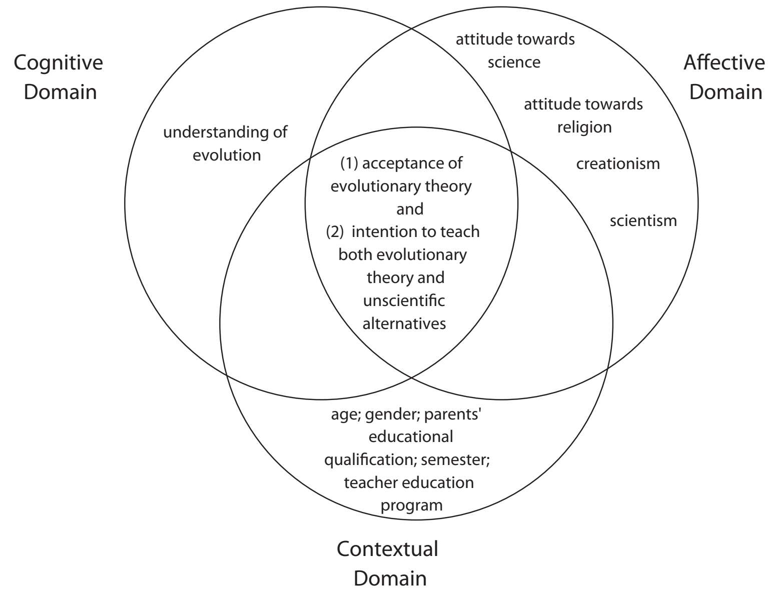

Figure 1 Adapted model of acceptance of evolutionary theory and intention to teach both evolutionary theory and unscientific alternatives based on Deniz et al. (2008).

the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK] 2008) schedule some biological contents (e.g., immunobiology) for academic-track teachers only. With regard to the common contents (e.g., evolution) for both pre-service teacher populations, they state that these contents have to be studied in more detail by academic than non-academic-track pre-service teachers. In contrast to this, the standards for pedagogical content knowledge (Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK] 2008) and pedagogical knowledge (Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK] 2004b) are comparable for both populations of pre-service teachers.

Data collection procedure

The study was conducted at eleven universities spread out all over Germany. It was embedded into the KiL-project, which is an interdisciplinary project measuring the professional knowledge of pre-service science and mathematics teachers. The study itself was conducted over a weekend and lasted four hours. Two trained test leaders supervised the study. They thanked the teachers for their participation and administered the first questionnaire (time for processing: 30 minutes), which included demographic questions and a general ability test (not subject of this article). After a 15-minute break, the second questionnaire, which included instruments that are not subject of this article as well as the instruments outlined below, was administered to the participants. Pre-service teachers got an allowance of €40 for their participation.

Measures

Dependent variables

Acceptance of evolutionary theory (ACCEPTANCE)

The 'Measure of Acceptance of the Theory of Evolution' (MATE) is a widely used instrument developed by Rutledge and Warden (1999) which comprises 20 Likert-type items (5 = Strongly Agree; 4 = Agree; 3 = Undecided; 2 = Disagree; 1 = Strongly Disagree). Because of the appearance of positively and negatively phrased items, the responses were recoded with the effect that responses indicating a high acceptance of evolutionary theory receive a score of 5, whereas responses indicating a low acceptance receive a score of 1 (Rutledge and Sadler 2007).

Intention to teach both evolutionary theory and unscientific alternatives (INTENTION)

Pre-service teachers' intention to teach both evolutionary theory and unscientific alternatives was assessed using two items ("Evolution and creationism should both be presented in the secondary school biology curriculum" [cf. Köse 2010, p. 193]); "Besides evolution, creationism should be equally added to the secondary school biology curriculum."). This measure also employs the same rating scale as used in the ACCEPTANCE measure. Responses indicating a high intention to teach both evolutionary theory and unscientific alternatives receive a score of 5, whereas responses indicating a low intention receive a score of 1.

Predictors

Predictor of the cognitive domain

Knowledge of evolution Pre-service teachers' knowledge of evolution was captured by the conceptual inventory of natural selection (CINS; Anderson et al. 2002). The CINS is a multiple-choice format instrument developed to measure 10 evolutionary concepts. It comprises 20 items which are scored dichotomously.

Predictors of the affective domain

Attitude towards religion and science, scientism, and creationism Pre-service teachers' attitude towards religion (7 items), their attitude towards science (6 items), scientism (7 items), and creationism (6 items) were assessed by measures previously applied by Astley and Francis (2010). We employed the same rating scale used in the ACCEPTANCE and INTENTION measures. High ratings reflect higher characteristics of the respective scale.

Predictors of the contextual domain

We collected demographic information about the participants, such as gender (male = 1; female = 0) and age. In order to gain information about the socio-economic context of the participants, we asked for the highest educational qualification of their parents. Three categories were formed for the educational qualification of the parents: (1) university degree, (2) polytechnic degree, and (3) vocational training. Beyond that, information about the participants' university studies were collected, such as semester of university studies and teacher education program (academic = 1 vs. non-academic = 0) for which they are qualifying.

Data analysis

Rasch analysis

All measures were analyzed using the Rasch analysis. The Rasch analysis is based on a mathematical model within the Item Response Theory, which provides the means for dealing with ordinal data (Bond and Fox 2001; Wright and Mok 2000) as well as missing values (Smith 2000; Wright and Mok 2000). It converts ordinal data into interval measures, which allow the calculation of parametric statistics (Bond and Fox 2001; Smith 2000; Wright and Mok, 2000). Furthermore, the Rasch analysis predicts the probability with which a participant would answer a particular item (Smith 2000). This allows addressing problems that arise with missing data by reflecting item difficulty when calculating person ability scores. Imagine two individuals (A and B) answered a questionnaire about evolutionary theory consisting of five simple and five difficult dichotomous items. Person A omitted all the difficult items, whereas person B omitted only the simple items because they seemed not challenging. Assuming that both answered each of the five items correctly, a True-Score-Model would assign five credits to person A and five credits to person B, although B obviously is more knowledgeable than A. Person ability scores obtained by the Rasch analysis consider item difficulty. Therefore, a higher person ability estimate could be expected for person B than for person A. This is possible because person ability scores and item difficulty values are located on an interval scale with a common metric (Smith 2000).

Dealing with ordinal data as well as with missing data is based on the assumption that the statistical model fits the set of observed data. The discrepancy between the model and the data is expressed in a descriptive measure: the Weighted Mean Square (WMNSQ). WMNSQ is a residual-based fit index with an expected value of 1, ranging from 0 to infinity. WMNSQ values greater than 1 indicate that an item is less predictable than the model expects (i.e., underfit), whereas values smaller than 1 indicate that the item is more predictable (i.e., overfit; Wright and Linacre 1994). Although Wright and Linacre (1994) do not provide a hard-and-fast rule for WMNSQ values, they state that the WMNSQ should at least be located within the range of 0.5 to 1.5 for a productive measurement. However, using a tighter range is recommended by the authors. Therefore, we removed all items outside the tighter range of 0.7 to 1.3 from our analysis (see Table 2; cf. Wright and Linacre 1994). Besides using descriptive WMNSQ values for item selection, we used *t*-values to identify WMNSQ values significantly deviating from 1. Therefore, all items with *t*-values beyond the range of -2.0 to 2.0 were excluded from our further analysis.

The ACER ConQuest software (version 1.0.0.1; Wu et al. 2007) was used to analyze the data. Since CINS items (knowledge of evolution) are dichotomously scored, person ability and item difficulty were estimated with Rasch's simple logistic model. In contrast, items of the ACCEPTANCE and INTENTION measures as well as the measures of the affective domain are polytomously scored. Since all items shared the same response categories, two related extensions of Rasch's simple logistic model can be used for our data analysis. The rating scale model (RSM) is the more parsimonious one; it assumes that a particular measurement scale characterizes all the items in an instrument. Since this restriction often results in an insufficient model fit, we compared the RSM to an alternative model – the partial credit model (PCM) – which allows the thresholds to vary between items (Wright and Mok 2000; Wu et al. 2007). Person ability was estimated according to the WLE method (Weighted Likelihood Estimate). The accuracy of measurement was provided by EAP/PV (Expected A Posteriori/Plausible Value) reliability (Wu et al. 2007), which is shown for each scale in Table 2.

Table 2 Description of the scales and item fit values

Scale	*n* of items		Discrimination[a]		WMNSQ[a]		ZSTD[a]		Reliability[a]
	Original set	Reduced set	Min	Max	Min	Max	Min	Max	EAP/PV
CINS	20	19	.20	.65	0.90	1.16	−1.6	1.9	.78
ACCEPTANCE	20	17	.35	.62	0.76	1.20	−2.0	2.0	.98
Religion[b]	7	4	.61	.65	0.88	1.14	−0.9	1.0	.97
Creationism	6	4	.13	.50	0.83	1.08	−0.9	0.6	.63
Science[b]	6	5	.19	.37	0.90	1.13	−1.1	1.4	.65
Scientism	7	7	.11	.46	0.81	1.14	−2.0	1.5	.70
INTENTION	2	2	.68	.68	1.02	1.05	0.2	0.4	.84

Note. [a] = reduced set of items; WMNSQ = Weighted Mean Square; ZSTD = standardized z-values; EAP/PV = Expected A Posteriori/Plausible Value reliability; [b] = Religion: attitude towards religion; Science: attitude towards science.

Analyzing dimensionality

In order to analyze discriminant validity, a multi-dimensional Rasch analysis was applied to examine the empirical separability (i.e., empirical structure) of the measures which form the dependent variables of our study (ACCEPTANCE and INTENTION measure) as well as the measures which the predictors of the affective domain (Astley and Francis 2010). Concerning our dependent variables, we expected the acceptance of evolutionary theory and the intention to teach both evolutionary theory and unscientific alternatives to be two distinct attributes (or 'traits'). Therefore, we compared the fit of a two-dimensional model which is consistent with the structure theoretically assumed to a one-dimensional model which assumes a single latent trait. A similar analysis was applied to the measures within the affective domain. Since Astley and Francis (2010) claim that these measures discriminate between four attributes, we fitted a four-dimensional model to the data and compared the model fit with the corresponding fit values of a one- and a two-dimensional model (dimension 1: creationism and attitude towards religion; dimension 2: scientism and attitude towards science).

In order to decide which model fits best, the final deviance can be taken into account. The final deviance indicates the likelihood of the observed data to fit the assumptions of the estimated model. The smaller the corresponding value, the better is the model fit. A χ^2-test can be performed to explore whether two models significantly differ in fitting the data (Bentler 1990). Additionally to χ^2-statistics, information-based criteria such as Akaike's (1981) Information Criterion (AIC = deviance + 2 n_p) and Bayes' Information Criterion (BIC = deviance + [ln$N$] 2 n_p; Wilson et al. 2008) were employed. Although these criteria do not allow for a significance test between different models, they take the parsimony of the model into account. When comparing information-based criteria of different models, it is the general rule that the lower the coefficient is, the better the model fits the data (Schermelleh-Engel and Mossbrugger 2003; Wilson et al. 2008).

Results

Validity check

As previously mentioned, our study aims to investigate whether pre-service teachers' acceptance of evolutionary theory (ACCEPTANCE measure) and intention to teach both evolutionary theory and unscientific alternatives (INTENTION measure) are related to four selected attributes from the affective domain. These attributes are

Table 3 Item dimensionality test results using a Rasch analysis of 20 items of the ACCEPTANCE and INTENTION measures as well as 26 items applied by Astley and Francis (2010)

No. of dimen-sions	Rating scale model (RSM)			Partial credit model (PCM)		
	Deviance (no. of free parameters)	AIC	BIC	Deviance (no. of free parameters)	AIC	BIC
	ACCEPTANCE and INTENTION measures					
One	7428.821 (23)	7474.821	7548.131	6779.601 (74)	6927.601	7163.467
Two	6978.635 (25)	7028.635	7108.320	6302.884 (76)	6454.884	6697.125
	Measures of the affective domain (Astley and Francis 2010)					
One	8833.168 (24)	8881.168	8957.799	8205.346 (78)	8361.346	8610.396
Two	8143.129 (26)	8195.129	8278.146	7543.131 (80)	7703.131	7958.568
Four	7773.438 (33)	7839.438	7944.805	7283.975 (87)	7457.975	7735.762

Note. AIC = Akaike's Information Criterion; BIC = Bayes' Information Criterion.

(1) attitude towards religion, (2) attitude towards science, (3) scientism, and (4) creationism. Investigating these relationships presumes that the measures of both dependent and independent variables discriminate between different latent traits.

The discriminant validity of the ACCEPTANCE and INTENTION measures was investigated by comparing a two- and a one-dimensional PCM and RSM respectively. Table 3 shows considerably high deviance for the RSM, which indicates that the PCM fits the data better. Comparing the two- and one-dimensional PCMs, a χ^2-test indicates that the two-dimensional model fits the data significantly better, $\chi^2(2) = 476.72$, $p < .001$. This is confirmed by the information-based criteria AIC and BIC in Table 3. The latent correlation between both measures is negative, $r = -.51$, $p < .001$, which also supports the discriminant validity of the measures. Concerning the discriminant validity of the measures of the affective domain, the results in Table 3 indicate that in all dimensionalities, the PCM fits the data better than the RSM (cf. final deviance and information-based criteria). According to the information criteria, the best model fit is yielded by the four-dimensional PCM. This statement is confirmed by a χ^2-test comparing the four- to the two-dimensional PCM, $\chi^2(7) = 259.156$, $p < .001$.

Latent correlations between the four latent variables within the four-dimensional PCM are shown in Table 4. With regard to the discriminant validity, it is consistent that the two religious traits as well as the two scientific traits correlate positively with other, whereas the religious traits correlate negatively with the scientific traits.

Descriptive results for dependent variables

Rutledge and Sadler (2007) distinguish five categories to classify the acceptance level of a person responding to the ACCEPTANCE measure. We calculated participant sum scores from the responses to the original set of 20 items in order to apply these categories to our data. The individual sum scores may range between 20 ('very low acceptance') and 100 ('very high acceptance'). Our descriptive analysis shows that the German sample gets an average sum score of $M = 84.21$ ($SD = 9.76$), which corresponds to a 'high acceptance' level (cf. Rutledge and Sadler 2007). With reference to the INTENTION measure, our sample reaches an average sum score of $M = 4.13$ ($SD = 2.21$). As sum scores may range between 2 (very low intention) and 10 (very high intention), this indicates a relatively disapproving intention to teach both evolutionary theory and unscientific alternatives. For example, most participants refuse the statement that evolution and creationism should both be presented in the secondary school biology curriculum (only 16.6% agrees or strongly agrees).

Table 4 Latent correlations between latent traits in the four-dimensional PCM

Measure	1	2	3	4
1. Attitude towards religion	–			
2. Creationism	.74***	–		
3. Attitude towards science	-.21**	-.49***	–	
4. Scientism	-.28***	-.26***	.43***	–

**$p < .01$; ***$p < .001$.

Regression analysis

As stated before, the first aim of our study is to investigate whether pre-service teachers' acceptance of evolution (research question 1) and their intention to teach both evolutionary theory and unscientific alternatives (research question 2) are related to indicators of the cognitive, affective, and contextual domains. Correlation analyses were performed to identify indicators which are significantly related to ACCEPTANCE and INTENTION scores (see Table 5). No significant correlations were observed between ACCEPTANCE scores and the pre-service teachers' age or their parents' educational level. These indicators as well as scientism and semester were also not significantly correlated to INTENTION scores (all correlations bootstrap-type).

In order to find the most parsimonious set of variables which effectively predicts ACCEPTANCE and INTENTION scores, multiple regression analyses were performed with the structural equation software Mplus (version 5.21; Muthén and Muthén 2007). Since the assumption of normality was violated in some cases, bootstrap-type regressions (10,000 replications) were conducted, not imposing the assumption of normality in the case of the sampling distribution. Concerning the first research question, the ACCEPTANCE scores were used as a dependent variable, and all significant variables from our correlational analysis (see Table 5) were entered as predictor variables. The regression analysis (see Table 6) reveals that the model significantly predicts ACCEPTANCE scores, $p < .001$. R^2 for the model was .47. In terms of individual relationships between the predictors and ACCEPTANCE scores, creationism ($B = -0.52$, $\beta = -.39$, $p < .001$), attitude towards science ($B = 0.33$, $\beta = .29$, $p < .001$), knowledge of evolution ($B = 0.17$, $\beta = .17$, $p < .01$), gender ($B = 0.40$, $\beta = .13$, $p < .05$), and semester ($B = 0.08$, $\beta = .16$, $p < .01$) each significantly predicted ACCEPTANCE scores (see Table 6). This means that the tendency to hold a more creationist view is negatively related to the acceptance of evolution, whereas the acceptance of evolution benefits from a positive attitude towards science, a good knowledge of evolution, male gender, and advanced university studies. After controlling for these variables, an effect for attitude towards religion, scientism, and teacher education program could not be detected anymore.

Table 5 Means, standard deviation, and intercorrelations for acceptance of evolutionary theory (ACCEPTANCE measure), intention to teach both evolutionary theory and unscientific alternatives (INTENTION measure), as well as predictor variables from the cognitive (1), affective (2–5), and contextual domains (6–10)

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10
ACCEPTANCE	4.32	0.49	.37***	-.17*	-.51***	.46***	.18*	.07	.23**	.23**	.24**	-.04
INTENTION	2.12	1.10	-.29***	.24***	.42***	-.24***	-.05	-.04	-.21**	-.19*	-.10	.08
Predictor variable												
1. CINS	0.70	0.18	–	.05	-.31***	.12	-.16*	-.05	.14	.28***	.17*	-.03
2. Religion	2.16	1.30		–	.52***	-.10	-.20**	-.12	-.06	-.06	-.05	-.05
3. Creationism	1.32	0.56			–	-.24***	-.10	-.02	-.10	-.21**	-.05	.04
4. Science	4.09	0.55				–	.26***	-.02	.10	.14	.10	-.01
5. Scientism	2.67	0.67					–	-.04	.11	-.08	.03	.14
6. Age	22.82	2.48						–	.13*	-.05	.48***	.06
7. Gender	–	–							–	.14*	-.02	-.01
8. Track	–	–								–	.18***	-.02
9. Semester	4.79	2.47									–	.12*
10. Parents	–	–										–

Note. CINS = understanding of evolution; *Religion* = attitude towards religion; Science = attitude towards science; Gender: male = 1, female = 0; Track = teacher education program: academic = 1, non-academic = 0; Parents = parents' educational qualification: university degree = 1, polytechnic degree = 2, and vocational training = 3. $N = 166$ (Listwise deletion).
*$p < .05$; **$p < .01$; ***$p < .001$.

With regard to the second research question, INTENTION scores were used as a dependent variable, and all significant predictors from the correlation analysis in Table 5 were used as independent variables. The regression analysis (see Table 6) reveals that the model significantly predicts INTENTION scores, $p < .001$. R^2 for the model was .25. In terms of the individual relationships between the predictors and INTENTION scores, the tendency to hold a more creationist view is positively related to the intention to teach both evolutionary theory and unscientific alternatives ($B = 0.57$, $\beta = .27$, $p < .001$), whereas INTENTION scores significantly decrease when accompanied by a good knowledge of evolution ($B = -0.25$, $\beta = -.16$, $p < .05$; see Table 6). Furthermore, females reach significantly higher INTENTION scores than males. After controlling for these variables, a significant effect for attitude towards religion, attitudes towards science, and semester could not be detected anymore.

Relationship between acceptance and preference

As stated in our third research question, we are interested in to what extent the acceptance of evolutionary theory is related to the intention to teach both evolutionary theory and unscientific alternatives. Our regression analyses above have shown that three indicators (knowledge of evolution, creationism, and gender) are significantly related to both ACCEPTANCE and INTENTION scores (see Table 6). Therefore, the relationship between acceptance and intention could be obscured or confounded by these indicators (Cohen and Cohen 2003). Actually, our analyses show that the relationship between

Table 6 Summary of the regression analyses for the variables explaining acceptance of evolutionary theory (ACCEPTANCE measure) and intention to teach both evolutionary theory and unscientific alternatives (INTENTION measure; N = 178)

Predictor(s)	*B*	*SE B*	β	R^2
ACCEPTANCE as dependent variable				.47
CINS	0.17	0.06	.17**	
Religion	0.03	0.02	.09	
Creationism	−0.52	0.09	-.39***	
Science	0.33	0.07	.29***	
Scientism	0.13	0.09	.09	
Gender	0.40	0.17	.13*	
Track	0.08	0.15	.03	
Semester	0.08	0.03	.16**	
INTENTION as dependent variable				.25
CINS	-.0.25	0.12	-.16*	
Religion	0.04	0.04	.08	
Creationism	0.57	0.18	.27***	
Science	−0.24	0.12	-.13	
Gender	−0.66	0.31	-.14*	
Track	−0.23	0.29	-.06	

Note. *B* = unstandardized regression coefficients; CINS = understanding of evolution; Religion = attitude towards religion; Science = attitude towards science; Track = teacher education program; *SE B* = standard error of *B*; β = standardized regression coefficient.
*$p < .05$; **$p < .01$; ***$p < .001$.

ACCEPTANCE and INTENTION scores adjusted for the indicators is considerably weaker (bootstrap-type partial correlation: $B = -0.26$, $\beta = -.16$, $p < .05$) than the relationship which has not been adjusted (bootstrap-type product–moment correlation: $B = -0.90$, $\beta = -.38$, $p < .001$).

Mediation analysis

As outlined above, the regression analyses have shown that three indicators (knowledge of evolution, creationism, and gender) are significantly related to both ACCEPTANCE and INTENTION scores (see Table 6). As we assume that acceptance unilaterally affects intention (not vice versa), we are interested in whether acceptance transmits the effect of the indicators to intention. In other words: Does acceptance represent a generative mechanism (i.e., a mediator) through which indicators 'affect' intention? We performed a detailed mediation analysis (MacKinnon et al. 2007) to answer this question. The tests of the conditions for the mediation analysis will be outlined below; the results of the final path model are presented subsequently.

Testing conditions

According to Baron and Kenny (1986), there are three conditions to be checked before conducting a mediation analysis. Firstly, the outcome variable (INTENTION scores) needs to be related to the potential predictors (i.e., knowledge of evolution, creationism, and gender; regression equation 1). This condition was met for the knowledge of evolution ($B = -0.25$, $\beta = -.16$, $p < .05$), creationism ($B = 0.74$, $\beta = .35$, $p < .001$), and gender ($B = -0.73$, $\beta = -.15$, $p < .05$). Secondly, the mediator (ACCEPTANCE scores) needs to be related to the potential predictors (regression equation 2). This condition also was met for the knowledge of evolution ($B = 0.22$, $\beta = .22$, $p < .001$), creationism ($B = -0.56$, $\beta = -.42$, $p < .001$), and gender ($B = 0.46$, $\beta = .16$, $p < .05$) as well. Thirdly, the mediator (ACCEPTANCE scores) needs to be related to the outcome variable (INTENTION scores) when the outcome variable is regressed on the mediator as well as on the potential predictors (regression equation 3). Results show that ACCEPTANCE scores are significantly related to INTENTION scores ($B = -0.27$, $\beta = -.17$, $p < .05$) when adjusted for the knowledge of evolution, creationism, and gender; this indicates that the third condition was met as well.

Testing significance

After having tested the conditions for mediation, we explored whether the relations between INTENTION scores (outcome variable) and the predictors diminish in regression equation 3 (acceptance as further predictor) in comparison to regression equation 1 (acceptance not included; see above). Actually, our results show that the relations (cf. regression equation 3) between INTENTION scores and the knowledge of evolution ($B = -0.19$, $\beta = -.12$, ns), creationism ($B = 0.59$, $\beta = .28$, $p < .001$), as well as gender ($B = -0.60$, $\beta = -.13$, ns) decrease; this points at mediation. To assure this suggestion, the statistical significance of the decrease, which is equal to the significance of the indirect effect between predictor and outcome variable (INTENTION scores) mediated by ACCEPTANCE scores (Baron and Kenny 1986; MacKinnon et al. 2007), should be tested. Therefore, a maximum likelihood path analysis with bootstrapped (10,000 replications) standard errors and confidence intervals for direct and indirect effects was performed.

A path analysis actually reveals that the strength of the relations between INTENTION and creationism as well as the knowledge of evolution is significantly lower in regression equation 3 (acceptance as further predictor) than in regression equation 1 (acceptance not included). This becomes apparent in the *p*-values of the indirect effect between INTENTION scores and creationism ($B = 0.15$, $\beta = .07$, $p < .05$) as well as the knowledge of evolution ($B = -0.06$, $\beta = -.04$, $p < .05$), but not in the *p*-value of the indirect effect between gender and INTENTION scores ($B = -0.12$, $\beta = -.03$, ns). Since INTENTION scores are still directly affected by creationism ($B = 0.59$, $\beta = .28$, $p < .001$), creationism seems partially mediated by acceptance; that is, creationism seems to exert both a direct and an indirect effect (mediated by acceptance) on intention to teach both evolutionary theory and unscientific alternatives. With reference to the knowledge of evolution, a significant direct effect towards INTENTION scores is not present anymore. Instead, the effect of the knowledge of evolution is fully mediated by acceptance. The specified model explains 33.2% of the variance of ACCEPTANCE scores as well as 24.4% of the variance of INTENTION scores.

Discussion

Descriptive results for dependent variables

The found acceptance of evolutionary theory in our sample of German pre-service biology teachers was even higher than the previously reported acceptance level of German adults or pre-service teachers (Graf and Soran 2011; Miller et al. 2006). Comparably high levels of acceptance were reported for US high school biology teachers (Trani 2004), educational professionals (Nadelson and Sinatra 2009), as well as Greek pre-service teachers in early childhood education (Athanasiou et al. 2012). In contrast, considerably lower levels were reported for Turkish pre-service science and biology teachers (Akyol et al. 2010; Deniz et al. 2008), US high school students (Cavallo and McCall 2008), and US non-major biology students (Rutledge and Sadler 2007). These results are in accordance with the previously discussed effects of the cultural and educational background. With reference to the intention to teach both evolutionary theory and unscientific alternatives, the high rejection of German pre-service teachers to teach unscientific alternatives meets our expectations. Only 16.6% of the sample agrees or strongly agrees with the statement that evolution and creationism should both be presented in the secondary school biology curriculum, whereas 84.2% of the Turkish teachers do (Köse 2010). This seems much different in the US context. Nehm and Schonfeld (2007) report that about 50% of the American biology teachers prefer to teach some amount of creationism, whereas the other half prefers to teach evolution exclusively.

Predicting acceptance and preference

The main aim of this study was to contribute to a more comprehensive view on the acceptance of evolutionary theory and the intention to teach both evolutionary theory and unscientific alternatives. Conceptual ecology was identified as a conceptual framework which covers a variety of factors influencing the learning of evolutionary theory, and thus being relevant for both acceptance and intention. Within the conceptual ecology for evolution, Deniz et al. (2008) highlight the relevance of cognitive, affective, and contextual factors. Knowledge of these factors is a necessary step to understand pre-service teachers' acceptance of evolutionary theory and their intention to teach both evolutionary theory and unscientific alternatives.

Our results suggest that fostering the knowledge of evolution (cognitive domain) significantly increases the acceptance of evolutionary theory. Furthermore, it seems to decrease the intention to teach both evolutionary theory and unscientific alternatives. Evidently, only those pre-service teachers who are confident with evolutionary theory assign a central role to the theory. These findings are consistent with the conclusions of others on the importance of understanding for intention. Balgopal (2014, 28) points out that teachers often avoid teaching evolution if they do not understand key terms or processes. Our analyses further indicate that a refusal of creationism as well as a positive attitude towards science (both affective domain) both also foster the acceptance of evolutionary theory. Not surprisingly, creationism fosters the intention to teach both evolutionary theory and unscientific alternatives. Although many studies observe negative relationships between acceptance and religiosity (see above), we were able to show that this relationship disappears when controlling for other factors. Since creationism can be regarded as a special form of fundamental religiosity, it seems likely that it is rather the rejection of evolution due to a literal belief in special creation which constrains the acceptance and preference for teaching evolution. This interpretation is corroborated by the relatively high correlation between creationism and the attitude towards religion. However, being religious does not necessarily imply being creationist. This is exemplified by the official positions of the Catholic Church as well as of mainline Protestant seminaries. It is possible that previous studies might have been misled into assuming that religiosity decreases the acceptance and preference for teaching evolution, as they did not strictly distinguish between religiosity and creationism. With regard to our results, we conclude that the religiosity of pre-service teachers should not per se be regarded as a reason for the rejection of neither evolutionary theory nor its teaching in the science classroom. In summary, creationism and the attitudes towards science represent two potential candidates for an unknown affective factor proposed by Deniz et al. (2008). Within the contextual domain, gender and semester seem to be relevant for the acceptance of evolutionary theory; with regard to the intention to teach both evolutionary theory and unscientific alternatives it is gender only which seems to be relevant. With reference to gender, we found that female participants had a lower level of acceptance. Similar results were reported in previous studies (Losh and Nzekwe 2011; Miller et al. 2006), which attributed the lower level of acceptance to the higher level of religiosity of female participants. Nevertheless, we did not find any evidence for this explanation in our data, as there was no significant relation between gender and the attitude towards religion (see Table 5). Furthermore, we found a weak, but significant relationship between acceptance and semester, but no relationship between educational background of the parents and acceptance or intention. With regard to acceptance, this result deviates from previous studies, which report weak effects on acceptance (e.g., Athanasiou and Papadopoulou 2012).

Since evolutionary theory constitutes the unifying theory of modern biological sciences, teaching evolutionary theory is regarded as a key task of school biology courses. Several studies have shown that teachers' acceptance of evolutionary theory is related to teachers' instructional practice, which implies that teachers who accept evolutionary theory are more likely to teach it (e.g., Aguillard 1999). Thus, we expected that the intention to teach both evolutionary theory and unscientific alternatives – beyond the factors of the cognitive, affective, and contextual domains – is influenced by acceptance as well. As both acceptance and intention are significantly related to a set of common indicators (knowledge of evolution, creationism, and gender), this relationship is possibly masked. To uncover the relationship, we analyzed the relationship between both constructs by partialling out these indicators. Our analyses show that the relationship between acceptance and intention after controlling for the set of indicators has decreased by more than 50% compared to before controlling. As we were interested in how this decrease can be explained, we subsequently performed a mediation analysis. Our results show that the relationship between acceptance and intention (without controlling for the set of indicators) can partially be attributed to an indirect effect of the knowledge of evolution and creationism towards intention (mediated by acceptance).

Limitations and achievements

One limitation of our study is the cross-sectional design, which inhibits causal conclusions about the particular predictors on the acceptance of evolutionary theory and the preference for its teaching (and particularly the intention to teach both evolutionary theory and unscientific alternatives). Other limitations concern the applied measures. We used the MATE-instrument to measure the acceptance of evolutionary theory. On the one hand, it has been tested for use with students (Rutledge and Sadler 2007) and is frequently applied, but on the other, it has repeatedly been questioned with regard to its validity – in particular with respect to the discrimination between acceptance and knowledge (e.g., Konnemann et al. 2012; MU Smith 2010). Recently, Nadelson and Southerland (2012) tried to answer the validity question by presenting a new instrument, the I-SEA. However, they had to struggle with the conflations which the instrument presented, for example for the acceptance of micro- and macro-evolution. We hope that a more valid and less critical instrument for the measurement of acceptance is accessible soon. Knowledge of evolution was assessed by use of the CINS instrument (Anderson et al. 2002), which has been criticized and questioned for several reasons (Battisti et al. 2010; Nehm and Ha 2011; Nehm and Schonfeld 2008, 2010). In particular, Nehm and Schonfeld criticized the forced choice format (2008) as well as the neglect of psychometric standards and methodology (2010), and argued that the CINS can falsely overestimate student understanding of evolutionary key concepts (2008). Nehm and Ha (2011) subsequently investigated item feature effects and discussed the influence of the item context. Furthermore, Battisti et al. (2010) identified several distractors as being problematic. Nehm et al. (2012) in response presented a new instrument (ACORNS, Assessing Contextual Reasoning about Natural Selection) relying on open-response items, which can be used in future studies.

Furthermore, it is hard to make a statement if the preference measure actually validly captures future teaching practice. Beyond that, we failed to incorporate other relevant information such as pre-service teachers' religious affiliation and educational background. Consequently, the question whether attending parochial or state schools makes a difference for pre-service teachers' acceptance of evolutionary theory and the preference for its teaching, as it can be inferred from a study of Evans (2001), remains open. Beyond that, we could show that the relationship between acceptance and preference is obscured or confounded by several indicators (e.g., knowledge of evolution). Other relevant indicators related to acceptance (e.g., NOS) or preference (e.g., social setting, job security) were left aside. Therefore, a comprehensive analysis of indicators and a thorough discussion of their influence as well as interdependencies remains a desideratum of research. The review by Sickel and Friedrichsen (2013) examining literature for evolution education with a focus on teachers definitively builds an excellent starting point for further research.

Notwithstanding these limitations, it is our opinion that two points should be recognized concerning the quality of the study. Firstly, the comparability to existing studies is fairly good for the chosen sample, because many studies on both the acceptance and preference for teaching evolution are based on pre-service teachers. Secondly, the instrument quality was satisfying. We reported evidence for the validity of Astley and Francis' (2010) scales for the attitude towards religion and science, scientism, and creationism. Furthermore, we found evidence that empirically, acceptance and intention are two different constructs.

Conclusions

As reported above, the attitude towards religion has repeatedly been shown to provide a predictor for both the acceptance of evolutionary theory and the preference for teaching evolution. In contrast, we identified creationism – and not attitude towards religion – as a predictor and attributed this effect to the simultaneous inclusion of the attitude towards religion and creationism in our study. This interpretation should definitely be verified. Furthermore, it should be explored whether these findings can be generalized to include the US context, where the relation between the attitude towards religion and creationism might be closer than in Germany due to a different political and cultural climate (cf. Miller et al. 2006).

Referring to teachers' preference for teaching evolution, their subject matter knowledge (which we analyzed by using the CINS) is only one component of professional knowledge which might encourage teachers to teach evolution in the classroom. Recently, Sickel and Friedrichsen (2013) argued that pedagogical content knowledge should be an essential element in preparing teachers to teach evolution. Shulman (1986) describes teachers' pedagogical content knowledge as a second type of content-related knowledge which is necessary to make subject matter comprehensible – for example by providing appropriate teaching situations (Loughran et al. 2001). As research in evolution education has largely disregarded (pre-service) teachers' pedagogical content knowledge, future research needs to clarify whether a lack of pedagogical content knowledge could be responsible for a low preference for teaching evolution. To answer the question, tests need to be developed capturing (a) the knowledge of instructional strategies, which integrates the representation of subject matter and responses to specific learning difficulties and

(b) the knowledge of students' conceptions and preconceptions. Both (a) and (b) are regarded as the central facets of pedagogical content knowledge (e.g., Hill et al. 2008; Lee and Luft 2008; Park and Oliver 2008; Schmelzing et al. 2013). Balgopal (2014) recently identified pre-service teachers with high preference for teaching evolution but low subject matter knowledge. Similar results are expected for pedagogical content knowledge. Both deficits could be easily remediated by adequate learning opportunities focusing on knowledge gain without the need to change personality traits such as religiosity. Hence, teachers' willingness to teach evolutionary theory can be fostered in a way explicitly protecting the freedom of religion and belief.

Current studies show that evolutionary theory persists to be a controversial issue for secondary school students even in Germany (Basel et al. 2014). Thus, future teachers need to be prepared to deal with the controversy. One important option is undoubtedly a profound scientific university education. Accordingly, an obligatory evolution course for all biology teacher education programs has been demanded elsewhere (cf. Nehm and Schonfeld 2007). In Germany, official resolutions of the Secretariat of the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK] (2008) already realize this demand, as they define evolution as one of the mandatory subjects within biology teacher education. The high level of acceptance and the low intention to teach both evolutionary theory and unscientific alternatives found in our study might at least in part be attributed to this aspect of German teacher education. Hence, specifically designed teacher evolution education courses seem to be the method of choice. As our results underline the role of knowledge and knowledge for both the acceptance of evolutionary theory and the preference for its teaching – a result which is also supported by Akyol et al. (2012) – one important strategy is undoubtedly to foster a profound knowledge of evolution among future biology teachers. Furthermore, our results support approaches which try to improve the acceptance of evolutionary theory and the preference for its teaching by fostering positive attitudes towards science and reducing creationism. Finally, thorough intervention studies fostering the acceptance of evolutionary theory can be considered one of the primary objectives of future research both on the acceptance of evolutionary theory and the preference for its teaching.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
Authors contributed equally to this work. All authors read and approved the final manuscript.

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