Nordidactica – Journal of Humanities and Social Science Education
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Nordidactica 2014:1
ISSN 2000-9879
The online version of this paper can be found at: www.kau.se/nordidactica

Nordidactica
- Journal of Humanities and Social Science Education

2014:1

NORDIDACTICA – JOURNAL OF HUMANITIES AND SOCIAL SCIENCE EDUCATION
ISSN 2000-9879
2014:1 146-169

Epistemic beliefs and knowledge creation among upper-secondary students in transdisciplinary education for sustainable development

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Abstract: This study examines the epistemic beliefs of upper-secondary school students (n=208) involved in a transdisciplinary project regarding sustainable development. Specifically the dimensions of knowledge and knowing are explored and interpreted through a questionnaire, the Survey of Epistemological Beliefs in Transdisciplinary Education (SEBTE). A three-dimensional framework underpins the self-report paper-and-pencil questionnaire. Results from exploratory factor analysis suggest five factors or dimensions: Transdisciplinary knowledge, Quick knowledge, Certain knowledge, Simple knowledge and Collaborative knowledge. According to multiple regression analysis (MRA), three out of those dimensions of epistemic beliefs have a positive impact on the students' appreciation of the school project. Variables male and technoscientific students had a negative impact. The educational context of transdisciplinary education for sustainable development can be understood in terms of the learning metaphor of knowledge creation. Knowledge about students' epistemic beliefs is assumed to be a useful insight to both in-service and pre-service teachers embarking on transdisciplinary projects.

KEYWORDS: EPISTEMIC BELIEFS, TRANSDISCIPLINARITY, SUSTAINABLE DEVELOPMENT, EXPLORATORY FACTOR ANALYSIS, MULTIPLE REGRESSION ANALYSIS, EDUCATIONAL PRACTICE

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One day a week, she teaches sixth-form students in the technical programme at Uddevalla gymnasieskola, where she has been a teacher of English and Swedish for more than 25 years. Currently she is co-teaching in an interdisciplinary, introductory course of technology, and in a course of sustainable development for town planning.

1. Background

1.1 Introduction

One of the fundamental tasks of the Swedish upper-secondary school clearly stated in curriculum is that the teacher should give the students the opportunity to work interdisciplinarily (Skolverket [Swedish National Agency for Education], 2013). The history of interdisciplinary education goes back to the late 19th century when the term integration was used in Europe by Alexis Bertrand and Johann Herbart, in America by William James (Klein, 2006). In the 1920s the integrated curriculum and the project approach were linked to the American Progressivist movement. The 1960s and 1970s saw more worldwide innovative educational reform. During the 1980s and the 1990s thematic studies appeared, drawing on more than one school subject, and providing a multidisciplinary design (Klein, 2006). The term transdisciplinarity appeared in the 1970s to signal that earlier interdisciplinary and multidisciplinary approaches had been taken further in the transgression of disciplinary boundaries (Nicolescu, 2002). School subjects are sometimes looked upon as elementary versions of the academic disciplines. In fact the very names of the disciplines are transferred to the school level in the educational system, such as social science or physics. The transgression of school subjects can take place in similar manners, for example through team-teaching, where teachers of different disciplines teach together in a project or through a course that itself is transdisciplinary. Another way of transgressing the boundaries of the school subject is more physical, in the fact that the organization of teaching brings students out into the surrounding community to seek out both information and extramural experts to learn collaboratively from. In the theory of transdisciplinarity the transgression between the expert knowledge of institutions and society is recognized (Russell, 2008).

This interrelatedness between school and society has its roots in Dewey's thoughts about reflective learning in school and society (Hartman, 2003) and it is well supported by the Swedish national curriculum for the upper-secondary school:

> *[S]chool cannot on its own impart all the knowledge students will need. Consequently, it is essential that [the] school creates the best combination of conditions for the students' education, thinking and acquisition of knowledge. In this context, [the] school should make use of the knowledge and experience available in the surrounding environment (area).*
> (Skolverket [Swedish National Agency for Education], 2013, pp. 6-7)

The quote opens up for a transdisciplinary approach although both multidisciplinary as well as interdisciplinary approaches could be considered to meet these requests. The various concepts in the category of interdisciplinarity will be developed below. When students are involved in a transdisciplinary project, they may

meet not only different epistemologies, but also contradictory information and alternative perspectives, which means that they might have to grapple with cognitive conflicts. In this dialectic process, the individuals express their thoughts and opinions based on various knowledge bases and through a variety of integrative techniques, broad issues are addressed (Klein, 1990).

1.2 The educational project *Our Food!* and education for sustainable development (ESD)

The broad issue of the educational context where the present study is embedded is sustainable development. 351 post-secondary students from 16 schools in the region of Sweden called Region Västra Götaland took part in the project Our Food! in which the purpose was to publish a book and thereby increase public awareness ofthe knowledge and ideas of young people. The participants aged 16 to 19 supervised by their teachers facilitating access to extramural experts, wrote and published a book with a wide array of aspects on the theme. The project was transdisciplinary in so far that it was initiated and organized by an extramural organization, Global Forum, in Gothenburg. In this respect society was reaching in and school was reaching out regarding a relevant societal issue with a global concern.

For four months the students worked individually or in small groups guided by their teachers, but also with the access of 39 external experts in various fields in order to provide scientific support. A website was available with various references to recommended articles and reports and the contact information of the experts. An additional Facebook-group allowed for the students to communicate and display their work. Each participating school chose how to embed the project in their local enactment of the curriculum, so the situatedness of the project could be within an individual course or school subject or across the curriculum. The students had to meet a strict deadline with their manuscripts. They knew that their book would be published, sold in bookstores and handed out to the local area government. These aspects could have affected the students' evaluation of the project outcome. 105 out of 145 of the students' essays or mini-chapters were published[1]. They present facts and advice on a way forward for a society that is fair and sustainable. Subjects covered are for example: food waste, starvation, locally produced food, supermarkets and meat production.

The transdisciplinary project focusing food can be designated education for sustainable development (ESD). Sustainable development is a challenge for modern society. It raises issues as to how we can develop our society further in a way that is sensitive to the planet and its living beings. It represents a field of complex knowledge, comprising conflicting facts and contradiction. For educational practice this serves as a potential challenge when it comes to what to teach, how to teach it

[1] Magnusson, Å & Nilsson, B (2013) *Mat! 351 västsvenska ungdomar om global matsäkerhet och hållbar utveckling [Food! 351 young people in Western Sweden about global food security and sustainable development].* Göteborg. Tre böcker

(Wals & Jickling, 2002) and indeed how to assess what was learned. Sustainable development, as ill-structured (King & Kitchener, 1994) or wicked problems (Harris, 2010), are seen as drivers for a transdisciplinary approach (Russell, 2008). Sustainable development can also be understood as a complex heterogeneous domain (Bruce, 2004). Education for sustainable development is consequently a contested concept. It seems to evade definition and comprises conflicting and multiple meanings within various educational systems (Bengtsson & Östman, 2013; Wals & Jickling, 2002). Bernard Williams's (Kotzee, 2011) concept of thin and thick concepts can be used to understand such a polysemic concept as ESD. In short, the distinction between a thick and a thin concept is that the thick concept comprises a descriptive as well as an ecaluative aspect. By contrast, the thin is evaluative only. A typical thin concept is the word *right* and a typical thick concept is *wholehearted*. The thin concept is action-guiding with its normative content, whereas *wholehearted* has the dual character of being both action-guiding and world-guided. In order to be world-guided, the concept needs to relate to something that has really occurred in the world. Understood as a thin concept ESD carries no meaning in its own right, but it "structures" the way to act (Bengtsson & Östman, 2013). The ESD framework will not be fully developed here, but it underpins the educational context by linking environmental and democratic concerns (Wals & Jickling, 2002). In order to explore how students orient themselves in such a complex and ill-structured knowledge field as sustainable development and indeed education for sustainable development, the concept of epistemic beliefs was focused.

1.3 Epistemic beliefs

Educational research on epistemic beliefs takes the influential work of William G. Perry Jr as its starting point. His concern was students' response to a changing and pluralistic world (Perry, 1968). In a longitudinal study with college students at Harvard and Radcliffe during the fifties and early sixties, Perry and his team tried to illustrate a variety of responses to a culture of contingent knowledge and relative value. Starting with a measure referred to as *A Checklist of Educational Views*, CLEV, a sample of students was selected based on their results to cover student profiles ranging from dualistic to contingent thinkers. This sample was used to provide thick descriptions in continual interviews during their years at university. The research team created the developmental scheme from these interviews on the assumption that it is possible to identify a dominant form of structure for each person. In the tradition of Perry several models of epistemological development have been suggested through longitudinal studies (Belenky, 1986; King & Kitchener, 1994;)

Marlene Schommer (1990) further developed Perry's research. She extended the definition of epistemic beliefs as beliefs about the nature of knowledge and beliefs about knowing and how learning occurs. In addition she introduced a paper-and-pencil, self-completion questionnaire, the Epistemological Questionnaire (EQ) which has played a major role in subsequent research on epistemic beliefs (Hofer & Pintrich, 1997). Whereas Perry had been looking at the development of epistemological beliefs,

Schommer looked at the dimensionality of the belief system. The dimensions operate independently of each other, so the students might display various degrees of each dimension. She identified five epistemic belief dimensions: *The stability of knowledge*, *The structure of knowledge*, *The source of knowledge*, *The speed of knowledge acquisition* and *The control of knowledge acquisition*.

Hofer and Pintrich (1997) in their review article have questioned whether beliefs about learning and teaching should be considered part of epistemological beliefs as they do not explicitly deal with the nature of knowledge and knowing. Instead they argue that personal epistemology is made up by systems of beliefs regarding the nature of knowledge and the processes of knowing. Consequently they recognize four epistemological dimensions: *The certainty of knowledge*, *The simplicity of knowledge*, *The source of knowledge* and *The justification of knowledge*.

Some studies are interested in the development of epistemic beliefs, where aspects of naïve and sophisticated beliefs need be looked at in a critical way (Elby & Hammer, 2001, Greene, 2009). The developmental perspective with its origin in Perry's studies has it that epistemic beliefs become more constructive and availing, the more educated and cognitively developed the person is (Mason, et al., 2013). The development is also stage-like, between four and nine stages have been presented in the literature (DeBacker, 2008). Other studies are more interested in the dimensionality of the epistemic beliefs, although there have been difficulties in finding proposed dimensions empirically. (Bromme, et al., 2010). Several studies have established a connection between epistemic beliefs and educational outcomes (Buehl, 2008). Depending on whether the authors are interested in what epistemic beliefs are or what epistemic beliefs do, they operationalize their studies differently. Ever since the seminal research on epistemic beliefs initiated by Perry (1968), a large part of studies have been carried out with university or college students (Schommer, 1990 ; DeBacker, 2008; Hofer B. , 2004; Bråten, 2004).

In the present study attention was given to the dimensionality of the epistemic beliefs of post-secondary students, 16 to 19 years old, in a transdisciplinary context. The proposed dimensions in the present study are *the structure* and *source of knowledge*, well-established dimensions used by Schommer (1990) influenced by Perry (1968); and the *justification of knowledge*, also used by Hofer and Pintrich (1997). Two of Hofer & Pintrich's dimensions, the *certainty* and the *simplicity* of knowledge can be seen to fall within *the structure of knowledge* in the present study. The educational implication is that epistemic beliefs are essential in reasoning and critical thinking and therefore relevant to explore in order to understand and develop educational practice (Schommer-Aikins, 2004)

1.4 Transdisciplinarity

Transdisciplinarity is used in a broad sense in this article. First, it is used to denote an organizing principle of education. In the sense that a theme is taught across the curriculum, transdisciplinary education is sometimes interchangeable with interdisciplinary education, which rather is an attempt to teachacross school subjects.

The prefix, inter- refers to the common ground between disciplines (Harris, 2010, p. 4), or school subjects. Transdisciplinarity combines but also rises above the principles and forms of thought in multi- and interdisciplinarity (Ramadier, 2004). In interdisciplinarity, knowledge is reinterpreted. The aim of participants is to share a common model, to achieve synthesis and to take onboard principles or concepts from one of the participators. Multidisciplinarity, by contrast, offers a recognition of differences, but lacks the aim of unity. Translated into education multidisciplinarity would correspond to school subjects working with the same issue but in a compartmentalized way, without transgressing any disciplinary boundaries. The participating educators or researchers can thus be referred to as "epistemological silos" (Miller, et al., 2008). They all work from their individual perspectives with a shared issue but without meaningful or real integration. Ramadier suggests that disciplinary thinking is present in both multi- and interdisciplinarity, but transdisciplinarity breaks away from this. In this study transdisciplinarity is being used instead of interdisciplinarity, to convey a more radical integration of knowledge. The Latin prefix TRANS- means, beyond and over. The direction of this movement can be horizontal and vertical. When horizontal the movement is across disciplines. The individual discipline is transgressed, which could take place in multi- or interdisciplinarity, whereas the vertical movement, above suggests transcendence. Transdisciplinarity can in that interpretation take on a metalevel and become a supradiscipline, transcending the structure of disciplines in academia (Bruce, et al., 2004). Ramadier argues that transdisciplinarity is between, across and beyond any discipline. It is rather the problem or issue that drives research or knowledge construction than the various disciplines (Bruce, et al., 2004). Through transdisciplinary educational projects new knowledge is created by students collaborating with each other, their teachers or other experts and professionals. The problem itself reaches out towards various knowledge domains, whether they will be found in institutions, professional or more informal contexts. It could also be relevant to consider the direction of the movement of multidisciplinary as well as interdisciplinary knowledge, which is centripetal contrary to the movement of transdisciplinarity, which I interpret to be centrifugal. Interdisciplinarity and multidisciplinarity have a centripetal movement in the problem solving process. Various disciplines come together to solve a problem. A complex socio-scientific or "wicked" problem (Harris, Brown, & Russell, 2010) is approached not only in school and across curriculum, but also beyond the curriculum-based school subject, as the project involved extramural experts as co-educators. Second, transdisciplinarity has been described as a way of collectively understanding an issue (Harris, Brown, & Russell, 2010, p. 4).

There seems to be two traits in transdisciplinarity: one is boundary crossing, the need to break away from traditional discipline specialization, the other the urge to transgress the gap between theory and practice (Horlick-Jones & Sime, 2004). In educational terms this can be translated into school reaching out to society for two reasons. One reason might be to actually solve a problem, or gain knowledge that school cannot itself provide. The other might be an attempt to cross the border

between school as not-the-real world and society as authentic reality. In the Scandinavian tradition of project work, which is transdisciplinary in both ways, there is a strong sense regarding the content of the project. Students should practice a critical attitude towards societal issues, which can be contrasted to the North-American tradition, which focused the method as a means of achieving democratic skills (Säljö, Jakobsson, Lilja, Mäkitalo, & Åberg, 2011, p. 63).

Transdisciplinarity is clearly linked to a holistic world view, which recognizes the connectedness between individuals. Values are founded in the relatedness and this relatedness provides a context for morality (Miller, 1986). In a holistic curriculum the affective and the cognitive are considered and the education relates to the whole child (Miller, 1986) and his or her relatedness in the world. The similarity to the transdisciplinary ethic can be revealed by the quote of Article 13 in Manifesto of transdisciplinarity:

> *The transdisciplinary ethic rejects any attitude that refuses dialogue and discussion, regardless of whether the origin of this attitude is ideological, scientistic, religious, economic, political or philosophical. Shared knowledge should lead to a shared understanding based on an absolute respect for the collective and individual Otherness united by our common life on one and the same Earth.* (Nicolescu, 2002, p. 151)

2. Research questions

The overall aim of this study is to explore an educational context, which concerns the interrelationships between students' concepts of knowledge or epistemic beliefs, transdisciplinarity, as the mode of teaching and sustainable development, as the content knowledge. In this context it becomes relevant to understand what those epistemic beliefs may *be*, *do* and *mean*.

The following research questions are addressed in this paper:

1. What are the dimensions of epistemic beliefs among upper-secondary students involved in transdisciplinary education for sustainable development?

2. Is there a relationship between students' background variables: gender, age and educational programme and the dimensions of epistemic beliefs?

3. Is there a relationship between students' evaluation of the project experience and the dimensions of epistemic beliefs?

4. Is there a relationship between the students' background variables: gender, age and educational programme and the evaluation of the project experience?

3. Method

3.1 Participants

The participants in the project came from 14 upper-secondary schools and 2 folk high schools (independent adult education colleges). Educational programmes were represented according to Table 1, the mode being Social science programme.

TABLE 1.

Frequency of educational programmes among participants in the SEBTE questionnaire.Gender: F=117, M=76, Missing=15 (7,2%); mean age 17. 15, SD=0.92.

Educational Programme	Frequency	Percent
Economics	5	2,4
Technology	49	23,6
Social science	115	55,3
Handicraft	1	,5
Natural science	2	1,0
Natural resource use	8	3,8
Total	180	86,5
Missing (programme not reported)	28	13,5
Grand Total	**208**	**100,0**

3.2 Data collection

The data was collected through a questionnaire which was administered when the manuscript of the book of the educational project *Our Food!* was finished and Global Forum invited writers and teachers together with an expert panel, to discuss the theme of the project at a conference centre. A few students presented their chapters on stage. Not all of the 351 students participating in the project were present at the conference and there is no record of which schools attended. However, 59 percent of the study population were present and responded to the paper-and-pencil questionnaire. The time allocated for the questionnaire was 15 minutes plus a subsequent coffee break of 20 minutes. Due to organizing reasons the questionnaire was handed out to the students as they entered the conference hall and in total the students had the questionnaires at hand for a minimum of one and a half hours.

3.3 Research instrument and its development

In order to address the research questions a self-completion, closed-ended questionnaire: a *Survey of Epistemological Beliefs in Transdisciplinary Education* hereafter referred to as SEBTE was constructed. The SEBTE questionnaire consists of two parts. Part A contains 26 domain-general items regarding the concepts of knowledge and knowing. Part B contains 5 items which aim to evaluate the respondents' evaluation of the outcome of the project *Our Food!*

A Lickert scale was used in the questionnaire. Between the two end points with the descriptions *Not at all* and *Yes, absolutely* respectively, there are six boxes with ordinal numbers, going from 1 through to 6.The opposite categories correspond to natural, everyday speech among students 16-19 years old. Cohen et al refer to the type of rating scale used as a semantic differential (Cohen, 2011). With six points there is no immediate middle category, which means that the students need to make an active decision when responding (Saris, 2007). It is supposed to prevent them from falling into a habit of ticking the middle box all the way through. In addition a *Not applicable* box was provided next to the scale in order to give the opportunity for respondents who do not want to give an answer to a specific item to be able to tick a box, which in turn will potentially keep him or her motivated to complete the questionnaire.

The questionnaire was contextualized through three previous questionnaires (See table 2), each conceptualizing epistemic beliefs as general domain. The three instruments have contributed to the conceptual model as well as providing validated items. The most influential questionnaire is that of Marlene Schommer's, mentioned previously. Her research concerned the dimensionality of students' epistemic beliefs students and how these beliefs affect comprehension (Schommer, 1990). Her instrument the Epistemological Questionnaire (EQ) contains 63 items organized into 12 subsets. These subsets were used in factor analysis. Schommer rendered a four-factorial solution. Schraw (2002), made an adaption of Schommer's instrument, the Epistemic Belief Inventory (EBI). It contained 32 items, and they obtained five factors; actually those that Schommer had hypothesized, namely: *omniscient authority*, *certain knowledge*, *quick learning*, *simple knowledge* and *innate ability*. Wood & Kardash (2002) retained 38 items out of 80 after several exploratory factor analyses. Apart from the proposed dimensions the *speed* and the *structure of knowledge*, three novel dimensions were proposed: *Knowledge Construction and Modification*, *Characteristics of Successful students* and *Attainability of Objective Truth*. In SEBTE there has been some moderating of the wordings of the original items in English and of course the items were translated into Swedish. The questionnaire was piloted in several steps and items were "casted" individually with students of a similar category as the respondents. The item casting was inspired by Saris & Gallhofer (2007).

TABLE 2

SEBTE-items used in or adapted from previous instruments and SEBTE-original items. For English, please confer table 3.

	Schommer (1990) SEQ	Schraw et al (2002) EBI	Wood , Kardash (2002) EBS	Grice (2013) SEBTE
1. Det som är sant idag kommer att vara sant imorgon.	x	x		
2. Teoretisk kunskap är mer värdefull än praktisk.				x
3. Lärare skall fokusera på sådant man vet säkert och inte på sådant som forskarna är oense om.	x	x		
4. Min mesta kunskap får jag genom skolan.				x
5. Forskning ger kunskap jag kan lita på.			x	
6. Jag får kunskap genom att samarbeta med andra elever.				x
7. Mycket kunskap får jag utanför skolarbetet.				x
8. Det är en viktig kunskap att kunna söka och värdera information.				x
9. Elever som förstår snabbt klarar sig bäst i skolan.	x	x		
10. Den kunskap jag får i skolan kan jag lita på gäller.			x	
11. Det finns frågor som experter inte har det rätta svaret på.	x		x	
12. Kunskap har ett eget värde i sig.				x
13. Den största visdomen är inte att ha svaret, men att veta hur du får svaret.	x		x	
14. Det är intressant att fundera på frågor som experter inte är eniga om.	x			
15 Vissa personer har en medfödd förmåga att ta till sig ny kunskap.	x	x	x	
16. Om vetenskapsmän arbetar tillräckligt hårt kan de hitta svaren till alla frågor.	x		x	
17. I skolarbetet koncentrerar jag mig på faktakunskaper.	x			
18. Att arbeta med frågor som vi inte har möjlighet att hitta ett entydigt svar till är bortkastad tid.	x	x	x	
19. Jag funderar ofta på om det jag läser är sant.	x			
20. Att jobba en längre tid med ett svårt problem lönar sig bara för smarta elever.		x	x	
21. Jag lär mig bäst när jag arbetar i projekt med flera skolämnen.				x
22. Kunskap får jag bäst när jag arbetar med ett skolämne i taget. (reversed in analysis)				x
23. Jag försöker kombinera den kunskap jag får i olika skolämnen.	x			
24. Kunskap som jag får i ett ämne har jag ofta nytta av i ett annat ämne.				x
25. De riktigt smarta eleverna behöver inte jobba hårt för att lyckas i skolan.	x	x		
26. Det är förvirrande att kombinera det jag redan vet om ett ämne med det som står i läroboken.	x		x	

3.4 Sample characteristics

IBM SPSS version 21 was applied for descriptive and inferential statistics. Cronbach's Alpha is .731 for the 26 items in section A of the questionnaire and .827 for the 5 items in section B, which motivates that all items are retained for the analyses. Values above .7 are considered to corroborate internal consistency between the items of a questionnaire (Barmark, 2009). This means that all the items seem to measure the same construct.

The average number of missing values of the 26 domain-general items in section A is 8% and of the 5 evaluative items in the questionnaire 15%, which is quite a large amount. Listwise deletion in SPSS limited the valid number of questionnaires to 92 and only 42 percent of the responses were used. Missing data analysis gave that only 34 % of the questionnaires were completed fully, but all the questionnaires contained some missing information in terms of "not applicable" or non-response. However, according to Little's MCR test (Sig=.892), the missing values are not statistically significant which means that the null hypothesis cannot be rejected. In other words

values are missing in a random way and imputation of values is possible. In order to gain more power and not to reduce the sample size, replacement with means was carried out before analyses.

In the questionnaire three background variables were asked for: age, sex and educational programme. This information was requested in the last page of the questionnaire, which might explain for why some information is missing. Sex was not stated in 7,2% of the cases (valid count 193), age was missing in 9,1% of the cases (valid count 189) and educational programme was not stated in 13,5 % of the cases (valid count 180). Out of the 208 respondents: 56 % were female, 37% male, 7% non-response. The age span was from 15 to 20 years old, with 24 % aged 16; 35 % aged 17 and 27% aged 19.

For statistical purposes the participants were divided according to their fields of study into three categories: *socio-economic students*, *techno-scientific students* and *other*. In the first category: the students of economics were put together with students of social science as it can be assumed that their epistemological beliefs are related (Jehng, et al., 1993). On similar grounds the category of techno-scientific students was formed. Nine students from vocational educational programmes were put into the non-response group *other students*. These new variables were used in the subsequent analyses.

Principal Component Analysis (PCA) has frequently been used as the first step in explorative factor analysis. The purpose is to identify and later analyse the latent factors among the manifest variables in the data. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy at .681 motivates a PCA. Furthermore, a correlation matrix in SPSS could establish that the variables covary. The communalities, the amount of explained variance in each variable, ranged from 0,4 and 0,7 and in the initial 8 component factor analysis (or PCA) 60% of the total variance was explained.

4. Results

4.1 Explorative factor analysis

Through Varimax rotation, a five-factor solution with a total of 47,5% explained variance was obtained based on eigenvalue > 1-criterion and an inspection of the scree-plot. An argument for limiting the number of factors is that a simple solution with fewest possible factors is believed to have best external validity (Henson & Roberts, 2006).In addition, five factors or components, which is the appropriate term for PCA, has been yielded or proposed by instruments exploring domain-general epistemic beliefs (Schommer, 1990, Jehng, 1993). As the instrument includes 14 out of 26 items from Schommer's questionnaire an explorative factor analysis was run on those 14 items, which also rendered a five dimension factorial solution according to the scree plot with the Kaiser criterion. The total variance explained was 60 %.

A three-factorial solution was further tested. However, the communalities decreased considerably and only 36% of the variance could be explained. The scree

plot also supported a five factor solution. In table 3 below factor loadings are presented in descending order: *Transdisciplinary knowledge, Quick knowledge, Certain knowledge, Simple knowledge and Collaborative knowledge*. An interpretation of the explorative factors is presented under discussion.

TABLE 3

Factor loadings of Varimax rotated five-factor model.

		Component				
		1	2	3	4	5
Transdisciplinary knowledge	8. Knowing how to find and evaluate information is important.	,68	-,06	,10	,07	-,04
	14. I find it refreshing to think about issues that experts cannot agree on.	,65	-,18	,20	,00	,16
	24. Knowledge I gain in one subject I can often make use of in another subject.	,63	-,04	,16	,02	,19
	11. Often, even advice from experts should be questioned	,61	-,03	-,13	-,06	-,09
	7. A great deal of knowledge I acquire out of school.	,61	-,03	-,13	-,06	-,09
	23. I try my best to combine information across chapters or even across classes.	,57	-,03	,12	,15	,25
	12. Knowledge has a value in its own right.	,55	-,13	,09	,30	-,10
	19. I often think about whether what I read is true	,50	,06	,22	-,18	,13
Quick knowledge	20. Working hard on a difficult problem for an extended period of time only pays off for really smart students.	-,06	,75	-,01	,03	-,01
	9. Successful students understand things quickly.	,11	,66	,05	,05	-,03
	26. You will just get confused if you try to integrate new ideas in a textbook with knowledge you already have about a topic.	-,11	,56	-,04	,36	-,05
	25. The really smart students do not have to work hard to do well in school.	-,13	,55	,16	,03	-,07
	18. It is a waste of time to work on problems that have no possibility of coming out with a clear-cut and unambiguous answer.	-,45	,44	,16	,42	,16
Certain knowledge	5. Scientists can ultimately get to the truth.	,33	-,01	,64	,09	,02
	10. The information we learn in school is certain and unchanging.	,03	-,05	,64	,10	,07
	17. When I study, I look for specific facts.	,15	,01	,61	,20	,10
	2. Theoretic knowledge is more valuable than practical.	,04	,35	,58	-,15	-,06
	1. What is true today will be true tomorrow.	-,05	,24	,49	,03	-,37

Simple knowledge	15.The ability to learn is innate	,13	,29	,04	,62	-,15
	13. Wisdom is not knowing the answers, but knowing how to find the answers.	,50	-,09	-,18	,60	,04
	3. Instructors should focus on facts instead of theories.	-,09	,09	,30	,55	-,15
	4. Most of my knowledge I gain through school.	-,14	-,35	,38	,49	,26
	16. If scientists try hard enough, they can find the truth about almost anything.	-,04	,26	,31	,39	,28
Collaborative knowledge	21. I find it that I learn best when working in projects involving several school subjects.	,14	,06	,15	-,02	,80
	r22. I learn best when (NOT) working with one school subject at a time. (reversed in analysis)	-,07	-,08	-,07	-,36	,56
	6.I acquire knowledge by cooperating with other students	,21	-,29	-,06	,13	,39

4.2 Factors affecting the students' appreciation of the ESD project according to multiple regression analysis

The objective of the exploratory factor analysis was to find out an appropriate number of factors and interpret what the factors *may be*. The relationship between observed variables and factors can be interpreted as causal. The underlying construct of the factor so to speak causes the responses to the observed variables (Henson & Roberts, 2006). By contrast, in a regression analysis the purpose is rather to see what the factors *do*. The analysis will add explanatory power to what the dimensions of knowledge *do*. Factor scores from the exploratory factor analysis were saved as interval variables and an indexed variable was made up of the five B-items in the questionnaire (See table 4), and was named ESD project evaluation correspondingly. Inter-item reliability analysis gave moderate Alphas (See table 5).

TABLE 4

Items from section B of SEBTE – index variable ESD project evaluation

B1. Have you been able to use knowledge from more than one school subjects in your project?
B2. Has the project given you knowledge about the possibility of sustainable development in society?
B3. Will you be able to use what you have learned in the project for other courses in your upper-secondary educational programme?
B4. Has the project aroused new interests or ideas for future studies or work?
B5. Has the project been meaningful?

TABLE 5

Descriptive statistics of variables for multiple regression analysis (N=208)including Cronbach's Alpha

Factoring and index variables	Minimum	Maximum	Mean	SD	Alpha
Factor 1 Transdisc knowledge	-2,67	1,77	,00	1,00	.766
Factor 2 Quick knowledge	-2,25	2,70	,00	1,00	.681
Factor 3 Certain knowledge	-2,44	3,14	,00	1,00	.607
Factor 4 Simple knowledge	-3,84	2,27	,00	1,00	.552
Factor 5 Collaborative knowledge	-2,64	2,75	,00	1,00	.461
Indexvar. ESD project evaluation	6	30	20, 71	5, 60	.823

Bivariate correlation analyses were run alternating between the variables in table 5 as dependent variables. There was no correlation between students' educational programme and any of the factors. Gender impacted factor 2 – quick *knowledge* and Aged 16 was significantly correlated with factor 4 – *simple knowledge.* With ESD project evaluation as the dependent variable *socioeconomic students* showed statistical significance and so did gender. Age, however, was not correlated with ESD project evaluation. In bivariate analyses between the factors as independent variables and ESD project evaluation as the dependent variable all but factor 4 *simple knowledge* showed statistical significance. The correlation between Factor 1 – Transdisciplinary knowledge and education for sustainable development project evaluation is exemplified in table 6.

TABLE 6

Correlation between variables Factor 1 Transdisciplinary knowledge (TD) and education for sustainable development project evaluation (ESD)

		TD	ESD
TD	Pearson Correlation	1	,326**
	Sig. (2-tailed)		,000
	N	208	208
ESD	Pearson Correlation	,326**	1
	Sig. (2-tailed)	,000	
	N	208	208

**. Correlation is significant at the 0.01 level (2-tailed).

With the help of histograms and plot diagrams (Normal Q-Q Plots), it was concluded that all the variables going into the multiple regression analysis are approximately normally distributed. As the index variables are based on an EFA with orthogonal rotation, the risk of multicollinearity should be small. Collinearity statistics were run for the variables during the regression analysis. The Variance Inflation Factor (VIF) varied between 1,0 and 1,2 and did not reach the critical value of 2,5 which would suggest serious collinearity problems (Djurfeldt, et al., 2010, p. 366)

A stepwise multiple regression analysis was conducted to evaluate whether both background variables and epistemic beliefs predict students evaluation of a specific school project *Our Food.* The five factors of epistemic beliefs were included as independent variables. *Age*, *sex* and *educational programme* were transformed into dummy variables to work along with the other independent variables. In the multiple regression model, ESD project evaluation was chosen as the dependent variable. Stepwise regression was applied, which rendered seven models as presented below in table 7. In the first step Factor 5 *Collaborative knowledge* entered and in step two Factor 1 *Transdisciplinary knowledge.* These factors explain most of the variance in the dependent variable. Factor 3 *Certain knowledge* follows suit but adds only little to the model. In steps 4-6 (models 4-6) *Male*, Factor 2 *Quick knowledge* and *TechnoScientific students* enter the model with negative coefficients. This means that male students on the technical or natural science programme and with the belief that knowledge is quick or does not happen at all, will score low in the evaluation of the school project. All together the seven variables that entered model 7 explain for 41, 1 % of the variance of the dependent variable. As the model is developed with one variable at a time, the standard error of the estimate has also been reduced with the seven independent variables in model 7.

TABLE 7

*Summary of MRA. Dependent variable: ESD project evaluation, standardized B coefficients, standard error in parenthesis. ***=p<,001. **=p<,01.*=p<,05*

Independent variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Factor 5 *Collaborative knowledge*	,403***	,403***	,403***	,420***	,418***	,413***	,412***
	(,357)	(,334)	(,325)	(,316)	(,310)	(,304)	(,300)
Factor 1 *TD knowledge*		,326***	,326***	,336***	,335***	,337***	,337***
		(,334)	(,325)	(,316)	(,309)	(,303)	(,299)
Factor 3 *Certain knowledge*			,212***	,229***	,227***	,222***	,221***
			(,325)	(,316)	(,310)	(,304)	(,300)
Male				-,210***	-,180**	-,117*	-,102
				(,647)	(,645)	(,675)	(,669)
Factor 2 *Quick knowledge*					-,168**	-,187**	-,190**
					(,314)	(,310)	(,305)
TechnoScientific students						-,176**	-,191**
						(,717)	(,711)
Factor 4 *Simple knowledge*							,140*
							(,310)
Intercept	20,712	20,712	20,712	21,667	21,531	21,862	21,849
Adjusted R^2	,158	,262	,304	,345	,369	,394	,411

5. Discussion

In the Swedish curriculum for upper-secondary school it is stated that

> *… school's task of imparting knowledge presupposes an active discussion about concepts of knowledge, about what knowledge is important today, what will be important in the future, and also about how learning and the acquisition of knowledge takes place.* (Skolverket [Swedish National Agency for Education], 2011, p. 6).

Transdisciplinary education as an approach to solving an ill-structured and complex problem such as sustainable development probably involves certain epistemic beliefs at play. A recurring notion around the epistemic beliefs is that they follow a developmental curve or continuum from naïve to sophisticated. This notion is sometimes introduced somewhat casually. Spiro, Feltovich and Coulson have looked at prefigurative schemas'[2] (Spiro, et al., 1996) impact on the learning experience. They have found that the same factors can lead to either failure or success. It all boils down to the context. The important conclusion to draw from this is that evaluating one epistemic belief over another, or a certain degree of this epistemic belief, should be approached with some care. In education, in an introductory course of a new subject, it might be more beneficial to the student if he or she adopts a more naïve attitude when treating "well-structured domains", claims Spiro et al. This logic opens up for another hypothesis. This hypothesis is that the sophistication of a person's epistemic beliefs does not rest in the construct itself, but rather in the management of the process, what Maggioni et al would refer to as epistemic cognition (Maggioni, 2008). To sum up, the most important finding by Spiro et al through their Cognitive Flexibility Inventory instrument is that this instrument is mainly concerned with the sort of belief that will work for the acquisition of knowledge in ill-structured and complex situations.

5.1 Interpretation of the factors of the EFA

As SEBTE is contextualized in three previous instruments, it seems relevant in the interpretation of the factors to connect to existing names of factors established in previous studies. *Simple knowledge* for example is a factor which has proved steady across several studies (Wood & Kardash, 2002). In the interpretation of the factors the number of items that make up the individual factor have been read and interpreted hermeneutically. One might refer to it as a qualitative text analysis of quantitative results. This explication of the dimensions can be seen as the development of theory, but simultaneously it addresses what the epistemic beliefs might mean to an educational practice. It is important to understand why the study and understanding of

[2] I interpret the prefigurative schemas as epistemic beliefs as they are defined as "understanding of what knowledge consists of and how it should be acquired" (p53). Furthermore, in a footnote the previous name of the assessment instrument used is revealed, Epistemic Belies and Preferences (EBP)

epistemic beliefs are important. Research on epistemic beliefs is "an attempt to understand the learner's perspective" (Schommer-Aikins, 2012: p 108).

5.1.1 Factor 1: transdisciplinary knowledge

The first factor has been named *transdisciplinary knowledge*. Knowledge is complex and even partially contradictory. It speaks of an evaluative epistemology in which the expertise is subjugated to evaluation. Expert authority is recognized but looked at in a critical manner. Knowledge evolves and can be used and created by the individual, in and out of school. The dimension seems to concern the nature and the source of knowledge. Knowledge has the ability to move between various domains and disciplines. There is a strong individualistic sense in this factor, the capacity of the subject to create knowledge.

5.1.2 Factor 2: quick knowledge

Learning quick and the speed of knowledge acquisition is a dimension found by previous instruments. It concerns how you come to know, quickly or not at all. It could be interpreted as a determiner of knowledge. Quick and effortless learning will bring about knowledge. There is a sense of difficulty in obtaining knowledge. A notion of grudge and a more passive stance emerge. This grudge is related to the confusion caused by encountering contradictory information and to the construction of knowledge.

5.1.3 Factor 3: certain knowledge

Certain knowledge was a dimension gained by Schommer (Schommer, 1990) and it appears as one of the subscales in EBI. This factor seems to deviate clearly from factor 1. It appears to comprise dimensions concerning the source and justification of knowledge. School and research are seen as the homes of knowledge, the basis for what is knowable. They provide justified true beliefs. There is an answer to all questions and you can find it. Knowledge is static and unchanging. You come to know through transmission. Knowing is to have been given or received. There is a sense of passiveness, a sense of reproduction rather than creation.

5.1.4 Factor 5: simple knowledge

The fifth factor seems to approach issues regarding the structure and stability of knowledge. Simple knowledge was a dimension also established by Schommer (1990). In fact two of Schommer's factors are merged in this factor; simple knowledge and innate ability. Simple knowledge suggests correct choices, right or wrong answers. It is related to the innate ability of coming to know. The self or subject does not stand out. Knowledge is simple and received in school without involving any construction by the self. It displays a belief in school as a place to learn stable knowledge.

5.1.5 Factor 4: collaborative knowledge

The fourth factor associates issues that might be referred to as *collaborative knowledge*, which one might argue could belong to the dimension of the structure of knowledge. Peers play a significant role in the creation of knowledge and integration of knowledge. Knowledge resides outside and between the subjects. It is interrelated.

5.2 Knowledge creation

Epistemic beliefs are suggested to have an impact on the learning processes (Stahl, 2011). In order to understand what the epistemic beliefs in the present study might mean, a model of the educational context is sketched in figure 1. In the model epistemic beliefs (EB) are at play with transdisciplinarity (TD) and the education for sustainable development (ESD). The knowledge creation as a metaphor of learning is introduced. and due to significant correlations between the epistemic beliefs/factors and the ESD project evaluation a metaphor of learning is introduced. It has its roots in organizational studies, and draws attention to epistemic issues in educational research. Hakkarainen and Paavola (2005) address this metaphor by comparing it to the metaphors of acquisition and participation (Sfard, 1998, p. 5). In a simplified way, one could argue that the acquisition metaphor of learning sees the individual as the unit of knowing. Knowledge is transmitted or even given to the individual. It should not be understood as a necessarily passive approach. Knowledge is also actively constructed by the individual. By contrast the unit of knowing in the participation metaphor is not the individual but the group or society. Knowing is participating in a social process, becoming a member of a community (Lave & Wenger, 1991: 31). Knowledge creation both combines and surpasses the previous metaphors as the unit of knowing are "[i]ndividuals and groups creating mediating artifacts within cultural settings" (Hakkarainen & Paavola, 2005, p. 541). The students in the present study indeed produce a mediating artifact, the published book on food, and a conceptual artifact regarding sustainable development, which makes it relevant to approach the knowledge creation metaphor.

New knowledge and knowledge creation are metaphors for both the content knowledge and the processes employed to gain or develop knowledge in transdisciplinary education, where a number of skills recognized as entrepreneurial skills are deployed, such as creativity, initiative, performativity (Ball, 2003) and courage. Lund and Hauge (2011) define new knowledge as new to the individual, but knowledge creation as a metaphor of learning opens up for various interpretations, not the least when it comes to the understanding of collective knowledge (Onof & Rolin, 2000) and action knowledge. The knowledge-creation metaphor is worth exploring for its educational implications.

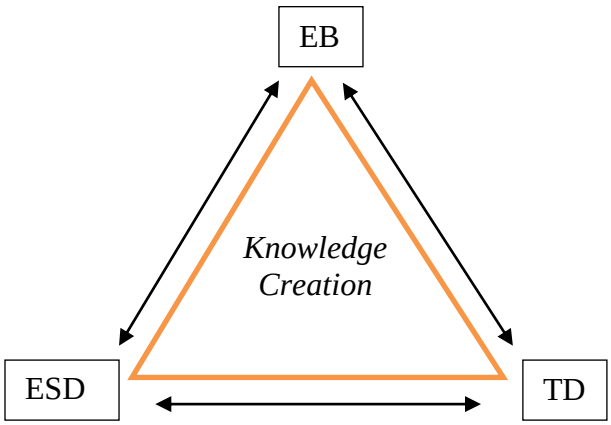

FIGURE 1

A model of the educational context. Epistemic beliefs, EB; education for sustainable development project, ESD, and transdisciplinarity, TD, are at play and knowledge creation as a metaphor of learning is used as an analytic lens.

For the purpose of a positive outcome of a project, such as the transdisciplinary project on sustainable development, three dimensions/factors were found to have predictive significance in a multiple regression analysis: TD knowledge, certain knowledge and collaborative knowledge. What these factors *do* is that they impact how much the students evaluated the present project. One factor was not included in the model at all, *quick knowledge* and *simple knowledge* added very little to the final model of the stepwise regression analysis. The three tentative dimensions of knowledge, which have guided the construction of the questionnaire: the *structure*, the *source* and the *justification* of knowledge have to some extent corresponded to the empirical results. The three prosed dimensions corresponded to five factors in the exploratory factor analysis. In our attempts to simplify and find fewest possible categories, we must not do so at the cost of understanding and meaning for the overall aim of the study. An alternative interpretation is that the proposed dimensions can be seen to operate on a meta-level in relation to the factors and could be used as descriptors for each empirically established factor in the study. The factors would in such a scenario represent concepts of knowledge which make up their own "domains" and can be identified through these descriptors.

6. Conclusion

In the present study focus was directed to how 208 upper-secondary students involved in transdisciplinary education for sustainable development estimated their epistemic beliefs through a self-assessed questionnaire. The first research question concerned the dimensions of knowledge that may appear in such an educational context. Three dimensions of the concepts of knowledge and knowing were proposed or hypothesized: the *structure*, *source* and the *justification* of knowledge. In the exploratory factor analysis five dimensions were established: *transdisciplinary*

knowledge, *quick knowledge*, *certain knowledge*, *collaborative knowledge* and *simple knowledge*. The number of dimensions is consistent with previous studies. Three of those dimensions: *certain knowledge, quick knowledge* and *simple knowledge* are similar to if not entirely identical with Schommer's dimensions (1990).

The second research question referred to the correlation between students' background details and the various dimensions or factors. Educational programme seemed to have no correlation with any of the factors. Females were negatively correlated with quick knowledge. This could indicate that females think that knowledge acquisition takes time and require hard work. Aged 16 (the youngest participants) were correlated with factor 4 *simple knowledge,* which might suggest that as first-year students in upper-secondary school they have still not developed a more complex notion of knowledge.

A third question concerned the impact of the epistemic beliefs on the students' evaluation of the education for sustainable development *Our Food*! In a stepwise multiple regression analysis, three dimensions/independent variables: *collaborative knowledge*, *transdisciplinary knowledge*, *certain knowledge* had the largest impact on the students' evaluation of the ESD project.

A fourth research question inquired into whether background variables such as age, sex and educational programme/field of study had any impact on the ESD project evaluation. Age did not enter the stepwise MRA at all. Males and technoscientific students did, however, decrease the value of the ESD project evaluation variable. Consequently females on the socioeconomic programmes will have appreciated the project more. The bivariate regression analysis between Factor 2 Quick knowledge was significantly correlated with male students. Quick knowledge/learning is a factor that in several studies have proved to have a negative impact on results and grades.

This study has its limitations. The empirical data consists of a single survey and repeated studies with the SEBTE questionnaire are needed to validate it. However, for the purpose of this paper, which takes the empirical results of the SEBTE questionnaire as a starting point for discussing epistemic beliefs in the context of knowledge creation in transdisciplinary education, the statistical analyses together with previous research can provide some answers to the research questions and play a role when in educational practice teachers need to find the source of students' shortcomings.

Further suggested analysis of the data in this study includes confirmatory factor analysis together with Latent class cluster analysis. See Magidson & Vermunt (2004) for a complete description. By examining the knowledge creation process through the awareness and understanding of epistemic beliefs, what they *are* and what they *do*, educational practice can potentially find what the results of the study could *mean* for transdisciplinary education. This knowledge could also be found useful in transforming the curriculum, in pre-service teacher education, in the development of in-service teachers and potentially in the learning processes of students.

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