Anima, Indonesian Psychological Journal
2014, Vol. 29, No. 3, 155-168

Evaluating the Validity of an Epistemic Belief Questionnaire: Evidence Based on Internal Structure, Content, and Response Process

Anindito Aditomo
Faculty of Psychology
Universitas Surabaya

The development of epistemic beliefs is regarded as an important goal of education. Three studies were conducted with preservice teachers in Australia to evaluate the validity of a new instrument that has the potential to measure sophistication of epistemic beliefs in a theoretically grounded manner. Two surveys gathered evidence on internal structure and content, and an interview study collected evidence on response process. Findings indicate that the original model and instrument required modifications. The modified instrument exhibited better internal structure. Interview data show that the instrument prompted respondents to think about the target constructs. However, the interview data also show that there are nuances in respondents' beliefs about scientific knowledge which were not captured by the written questionnaire.

Keywords: epistemic beliefs, scientific knowledge, validity, self-report questionnaire

Pengembangan keyakinan epistemologi (ilmu pengetahuan) pada siswa dianggap sebagai salah satu tujuan penting pendidikan. Artikel ini memaparkan hasil tiga studi pada guru-guru magang di Australia mengenai validitas sebuah instrumen baru yang mengukur perkembangan keyakinan epistemologi. Dua studi survei menyajikan bukti tentang konten dan struktur internal, dan sebuah studi wawancara memaparkan bukti mengenai proses merespons. Survei pertama menunjukkan bahwa model original dan instrumennya perlu dimodifikasi. Survei kedua menunjukkan bahwa instrumen hasil modifikasi memiliki struktur internal yang lebih baik. Data wawancara menunjukkan bahwa instrumen tersebut memaksa para responden untuk memikirkan konstruk yang disasar. Namun, data wawancara juga menunjukkan adanya nuansa dalam keyakinan responden tentang pengetahuan ilmiah yang tidak terungkap melalui kuesioner tertulis tersebut.

Kata kunci: keyakinan epistemologi, pengetahuan ilmiah, validitas, kuesioner lapor-diri

Epistemic beliefs refer to individuals' views and understanding about the nature of knowledge and knowing (Bendixen & Feucht, 2010; Hofer & Pintrich, 2002). Epistemic beliefs has become the focus of much research because of its influence on how students learn, and also because its development is regarded as a valued aspect of education (Bendixen & Feucht, 2010; Magolda, 2008; Magolda, King, Taylor, & Wakefield, 2012).

Psychologically, the development of epistemic beliefs is founded upon early cognitive achievement that begins at around the age of four, when children start to become aware that one's knowledge *re*presents, rather than simply copies or reflects, objective reality (Kuhn, 2000). By viewing knowledge as representations, children also start to become aware that knowledge could be false and that claims to knowledge may need to be evaluated. Such awareness paves the way for higher order cognitive processes valued in education, such as critical thinking and causal reasoning (Kuhn & Pearsall, 2000; Kuhn & Udell, 2003).

Studies of epistemological development often employ interviews and other intensive data collection methods (Kitchener & King, 1981; Magolda, et al., 2012; Perry, 1970/1999). To complement such methods, researchers and educators also need self-report instruments that allow the efficient collection of data across many individuals. The present study seeks to evaluate the validity of a new instrument which has the potential to assess the sophistication of epistemic beliefs in a theoretically sound manner (Greene, 2007; Greene, Azevedo, & Torney-Purta, 2008; Greene,

Correspondence concerning this article should be addressed to Anindito Aditomo, Faculty of Psychology Universitas Surabaya. Jalan Raya Kalirungkut, Surabaya 60293. E-mail: aditomo@staff.ubaya.ac.id

Torney-Purta, & Azevedo, 2010). This instrument has not been examined independently, and the present study contributes by evaluating its validity based on evidence regarding its internal structure, content, and response process.

To be sure, researchers have developed a number of epistemic belief measures (e.g. Hofer, 2000; Kardash & Howell, 2000; Schommer, 1990; Schraw, Bendixen, & Dunkle, 2002). However, existing instruments seem to have rather poor psychometric properties. For example, an independent examination of Schommer's, Kardash and Howell's, and Schraw et al.'s instruments found that all three had inadequate internal reliabilities and exhibited factor structures which did not fit with their underlying model (Debacker, Crowson, Beesley, Thoma, & Hestevold, 2008; Teo, 2013). An examination of Hofer's epistemic belief scale also shows that its factor structure does not conform to the hypothesized model, and at least two of its dimensions had low internal consistencies (Hofer, 2000).

Comparing between studies using different instruments, there are conflicting findings. With regards to factor structure, for instance, Schommer (1990, 1993) found that beliefs about certainty and simplicity of knowledge loaded onto different factors. However, Hofer (2000) found that the two beliefs loaded onto a single factor. Furthermore, while Schommer did not identify a factor representing authority as a source of knowledge, Hofer did. These inconsistencies may be related to the low unreliability of the instruments. They may also reflect contextual variations, suggesting that epistemic belief instruments are sensitive to context or culture. If so, this highlights is importance of establishing the validity of epistemic belief measures in new contexts.

The difficulty of measuring epistemic beliefs partly reflects conceptual and theoretical issues. One issue pertains the scope of the construct itself. There is ongoing debate about whether it should include beliefs about learning (such as whether the ability to learn is fixed or malleable), or whether it should be limited to beliefs about knowledge (its structure, certainty, and source). But even within the more limited scope of beliefs about knowledge, some instruments conflate items about knowledge with items about study preferences and/or strategies. For example, Schraw et al.'s (2002) epistemic belief inventory contained items such as "I like teachers who present several competing theories and let their students decide which is best." This item was meant to measure belief about the certainty of knowledge. However, disagreement to the statement could indicate a preference for teachers who give more direct instruction (rather than a belief that knowledge is certain).

In addition to construct scope, a second conceptual difficulty concerns the domain generality and specificity of epistemic beliefs. In their original versions, the epistemic belief measures discussed thus far were designed to measure domain-general beliefs. Thus, they included items such as "Most words have one clear meaning" (Wood & Kardash, 2002) and "I do not like movies that do not have an ending" (Schommer, 1990). But some researchers have argued that epistemic beliefs are more domain specific than assumed. One developmental model differentiates between epistemic beliefs about "brute" and "institutional" facts (Hallet, Chandler, & Krettenauer, 2002). The former refers to knowledge about the physical world, while the latter about the social world. Another developmental model proposes a finer grained distinction between five domains: personal taste, aesthetic judgment, value judgment, truth about the social world, and truth about the physical world (Kuhn, Cheney, & Weinstock, 2000). Both developmental models assert that more mature epistemic beliefs develop later for knowledge about the physical world, compared to other domains.

The third conceptual issue is related to how sophistication in epistemic beliefs should be conceptualized. From how most epistemic belief scores are measured in self report instruments, many researchers assume that epistemological sophistication means believing that knowledge is uncertain, subjective, and complex; as well as believing that authority cannot be trusted. But some aspects of this conceptualization could be problematic. From a philosophical stance, scientific knowledge (about the physical as well as social worlds) is best seen as models of things and processes that have an objective reality (Bhaskar, 1978; House, 1991; Kitcher, 2001). As such, knowledge is indeed constructed or the result of interpretive acts by knowing subjects (and thus "subjective"). However, the object of knowledge imposes constraints upon the scope of acceptable interpretations.

With regards to certainty, there are parts of the body of scientific knowledge that are regarded as quite certain (unlikely to change in a fundamental sense) by virtue of its dense interconnectedness with many concepts and its strong empirical basis (Kitcher, 2001). Similarly, with regards to beliefs about authority, it is likely that a strong disbelief in authority as a source of justification could often be

Table 1
Greene's Model of Personal Epistemology

Positions	Belief dimensions: Certainty and simplicity	Authority justification	Personal justification
Realism	Strong	Strong	Strong
Dogmatism	Weak	Strong	Weak
Scepticism	Weak	Weak	Strong
Rationalism	Weak	Moderate	Moderate

unproductive. Experts do have more authority on matters related to their expertise, compared to less knowledgeable individuals. Thus, an epistemologically sophisticated person would not disregard claims simply because they are justified based on authority. Rather, in modern societies in which knowledge has become highly specialized, the challenge is to evaluate the relevance of an authority's expertise and the claims made (Lutz & Keil, 2002).

The challenge is capturing such nuance using simple self-report instruments. A potential solution was recently proposed by Greene and colleagues (Greene, 2007; Greene, et al., 2008; Greene, et al., 2010), who combine stage and multidimensional models of epistemic beliefs. Following Hallet et al. (2002), these authors posit four increasingly sophisticated epistemological "positions": realism, dogmatism, scepticism, and rationalism. Each of these positions is characterized by a unique combination or pattern of beliefs corresponding to three dimensions: (1) the belief that knowledge is certain and simple; (2) the belief in authority as a source of justification; and (3) the belief in personal opinion and experience to justify knowledge claims.

What is novel in Greene et al.'s (2010) model is that it gives meaning to scores near the mid-point of a scale (i.e. neither agreeing nor disagreeing to an item). Such scores are seen as indicating a "moderate" belief. Thus, the "rationalist" position is defined as having moderate beliefs in both authority and personal justifications, combined with a weak belief in the certainty/simplicity of knowledge (see Table 1). Greene (2008) further predicts that epistemic development occurs more rapidly with regards to ill-structured knowledge domains (e.g. the social sciences and humanities), compared to well-structured domains (e.g. mathematics and the natural sciences). Thus, the authors predict that college students would exhibit a rationalist position for ill-structured domains, but dogmatist or sceptics positions for more well-structured domains.

Greene et al. themselves have evaluated the model among a sample of high school, undergraduate, and postgraduate students in the US. The results show that the instrument had acceptable reliabilities (above .7) except for the certainty/simplicity scale (Greene, et al., 2010). Confirmatory factor analysis results show that for the most part, the data had acceptable fit with the hypothesized model. Again, the exception was related to the certainty/simplicity dimension. These authors also examined whether respondents' response profiles (based on latent factor scores) conform to the positions proposed in the conceptual model. The results provided mixed evidence: most of the twelve profiles were interpretable within the model, but four were not (for example, strong beliefs in authority and personal justifications, but combined with a weak belief in simple/certain knowledge).

Study 1

While providing a potential solution to the challenge of measuring sophistication in personal epistemology using a simple instrument, Greene et al.'s model and instrument have not been independently evaluated. Considering that previous epistemic belief models and instruments have tended to fare rather badly when evaluated in different contexts and by different researchers (Clarebout, Elen, Luyten, & Bamps, 2001; Debacker, et al., 2008), the studies reported in this article seek to extend the evidence base regarding the quality of the instrument. Indeed, Greene et al. (2010, p.245) also recommended that "further bootstrapping between model revision and item design" needs to be conducted. In this first study, Greene et al.'s original instrument is evaluated in terms of its internal structure as one source of evidence regarding validity (AERA, APA, & NCME, 1999).

Method

The following questions were addressed: (1) How reliable are the scales measuring each dimension? (2) Does the factor structure reflect the three belief dimensions postulated by the model?

Participants. Evidence about internal structure was collected through a written survey among 114 preservice primary teachers enrolled in an introductory science course in an Australian university (85.1% female; median age 18 years). Preservice teachers were selected because the data was collected as part of a research project about the role of epistemic

Table 2
Reliability and Factor Structure of Greene et al.'s (2010) Epistemic Belief Instrument

Items	Dimension & reliability	*Corrected item-total correlation*	*Factor loadings* 1	2	3	4
In science, the truth means different things to different people.	Certainty/ simplicity *Cronbach's alpha* = .24	.00	- .31	.67	.02	.09
To know science well, you need to memorize what you are taught.		.07	.09	- .15	.47	.57
In science, what is a fact today will be a fact tomorrow.		.27	.32	.20	.73	- .22
Scientists' knowledge of the facts about history does not change.		.29	- .02	- .01	.82	.06
Science is so complex that humans will never really understand it. (reversed scored)		- .02	- .14	- .07	.14	- .75
If a scientist says something is a fact, I believe it.	Authority justification *Cronbach's alpha* = .87	.71	.77	- .27	.19	.08
Things written in science textbooks are true.		.71	.74	- .11	.37	.18
I believe everything I learn in a science class.		.76	.81	- .17	.08	.14
If a science teacher says something is a fact, I believe it.		.70	.85	- .03	- .13	.07
In science, everyone's knowledge can be different because there is no single absolutely right answer.	Personal justification *Cronbach's alpha* = .39	.38	- .21	.69	- .09	.14
In science, if you believe something is a fact, no one can prove to you that you are wrong.		.06	.41	.53	.16	- .23
In science, what's a fact depends upon a person's point of view.		.26	- .08	.60	.08	- .17
Scientific knowledge is all factual and there is no room for opinions. (reversed scored)		.17	- .43	.34	- .04	.15

beliefs in the planning of inquiry-based science lessons. The invitation to participate, the survey questionnaire, and participant information sheets which explains the study were distributed during a class session. Participation was voluntary.

Instrument. Greene et al.'s (2010) instrument consists of five items measuring a belief in the certainty/ simplicity of knowledge, four items measuring a belief in authority justification, and four items measuring a belief in personal justification (see Table 2). Each item has five response options from 1 ("strongly disagree") to 5 ("strongly agree").

Analysis. Cronbach's alpha was computed to evaluate internal reliability of each scale. Principle component analysis was performed to examine whether the items formed clusters corresponding to the three dimensions postulated by the model.

Results

Analysis results are displayed in Table 2. Only the 'authority justification' scale had exhibited acceptable reliability (*Cronbach* = .87). The other two scales had very low reliabilities, indicating that the items measured different constructs. Results of the exploratory factor analysis (*KMO sampling adequacy* = .76; *Bartlett's chi square statistic* = 395.54, $p < .01$) were in line with the reliability analysis. Four factors had Eigen values more than 1 and accounted for 60.1% of the variance.

Conforming to the model, the four items designed to measure the belief in authority justification loaded strongly together onto a single factor. Three of the four items designed to measure the belief in personal justification loaded strongly onto another factor. Two of the four personal justification items cross-loaded onto the first factor (together with items measuring authority justification). The five items designed to measure belief in the certainty and simplicity of knowledge were distributed across three factors.

Discussion

The results show that only the 'authority justification' scale in Greene et al.'s original instrument was reliable. The very low reliabilities of the other two scales indicate that the items in those scales measured different constructs. This interpretation is also supported by the factor analysis results, which show that items in the personal justification and certainty/simplicity scales load onto two or three factors. To understand why this might be the case, the content of the items were examined more closely. This examination reveals that the two scales seem to conflate different facets of epistemic belief.

With regards to the "simplicity/certainty" scale, two items clearly reflect belief in the certainty of knowledge: "In science, what is a fact today will be a fact tomorrow" (item #3) and "Scientists' knowledge of the facts about science does not change" (item #4). The other three items in this scale are more problematic. The two items that were intended to measure belief in the simplicity of knowledge were "To know science well, you need to memorise what you are taught" (item #2) and "Science is so complex that humans will never really understand it" (item #5). Item #2 confounds "simplicity" with expected learning behaviour in science classes ("memorise what you are taught"), while item #5 confounds "complexity" with the possibility of understanding science. The other item in this scale was "In science, the truth means different things to different people," which is closer to capturing belief about the subjectivity of knowledge, rather than the simplicity or certainty of knowledge.

With regards to items meant to measure personal justification, there seems to be a conflation of two rather distinct constructs: personal opinion in justifying (personal) knowledge claims, and the role of subjective interpretation in the construction of knowledge. The first construct is represented only by Item #11 ("In science, if you believe something is a fact, no one can prove to you that you are wrong"), whereas the second is represented by Item #10 ("In science, everyone's knowledge can be different because there is no single absolutely right answer."); Item #12 ("In science, what's a fact depends upon a person's point of view."); Item #13 ("Scientific knowledge is all factual and there is no room for opinion") and also Item 1 which was originally meant to measure certainty/ simplicity belief ("In science, the truth means different things to different people."). Higher scores on these items represent a stronger belief that scientific knowledge is subjective or involves inference and interpretation.

These results indicate that modifications to Greene et al.'s conceptual model and instrument are warranted. Such a modification is proposed and evaluated in Studies 2 and 3. Study 2 evaluates the modified model and instrument by examining evidence on internal structure. Study 3 evaluates the model and instrument based on evidence on response process.

Study 2

Results of Study 1 indicate that of three dimensions in Greene et al's original model, only one (authority justification) could be retained, while the other need required some modification. The 'certainty/simplicity' dimension was specified to measure one facet of certainty: the changeability of knowledge (i.e. whether knowledge changes). To measure this belief dimension, three new items were written and combined with two items from the original scale. The 'personal justification' dimension was modified to measure a belief in the role of subjective processes (inferences) in the construction of knowledge. Thus, the focus of this dimension shifts from *justifying* to *constructing* knowledge.

The modifications to the meaning the personal justification dimension resulted only in a minor change in the definition of the most naive position (realism). While someone who is epistemically naive could be expected to rely on personal experience to justify knowledge claims, that person is likely to have a weak (rather than strong) belief in the subjectivity of knowledge. In other words, the epistemically naive individual should see knowledge as being discovered from objective reality, rather than constructed based on prior knowledge.

The definitions of the other three positions are unchanged. *Dogmatism* is primarily characterized by a strong belief in authority (combined with a belief that knowledge is objective yet uncertain). Scepticism is primarily characterized by a strong belief that knowledge is subjective (combined with a belief that knowledge is uncertain and that authority cannot be trusted). Rationalism, the most advanced position, is characterized by a belief that knowledge while is uncertain, it is not entirely subjective (nor entirely objective), and that authority can sometimes be trusted and that knowledge.

What could be expected about first-year preservice teachers' epistemic belief positions? There are different predictions regarding this question. According to Greene et al. (2010), most beginning college students should still exhibit realist views with regards to well-structured domains. Greene et al. cited mathematics as an example as a well-structured domains and history as an ill-structured on. On this continuum, science could be seen as closer to the well-structured end, although somewhat more ill-structured than mathematics. Hence, Greene et al. would predict that most of the respondents in this study would be shifting from realism to either dogmatism or sceptics. In contrast, other developmental models such as Kuhn et al. and also Hallet et al. would predict that most of first-year college students would be more eipstemically advanced, either exhibiting sceptics (multiplist) or rationalist (evaluativist) views with regards to science.

Method

This study addressed the following questions: (1) How reliable are the scales in the modified instrument? (2) Does the factor structure reflect the three belief dimensions postulated by the modified model? and (3) How well does the epistemic positions postulated by modified model conform to the empirical response patterns?

Participants. Data for this study came from a survey with 81 preservice teachers (87.7% female; median age 18 years) who were from the same introductory science class as respondents in Study 1. This second survey was conducted approximately twelve weeks after the first survey. The questionnaires and participation information sheets were distributed during a class session. Participation was voluntary.

Instrument. From the 'certainty/simplicity' original dimension, two items were discarded and one was moved to the 'subjectivity' dimension. In replacement, three new items were written to measure the belief that knowledge is certain (or, more precisely, that knowledge does not change). These items are all reverse-scored: "In science, what is true today may be considered to be false tomorrow", "Scientific knowledge is constantly changing", and "Results of scientific research are always tentative". Thus, the 'certainty' scale now consists of five items. The 'authority' and 'subjectivity' scales each consist of four items (see Table 3).

Analysis. Cronbach alpha's was calculated to estimate internal consistency. Principle components analysis (PCA) was used to examine the factor structure. KMO sampling adequacy was .69 and Bartlett's chi-square was 406.78 ($p < .001$), indicating the PCA result is sufficiently reliable.

To see whether response patterns could be classified according to the model, each participant was classified as having a weak, moderate/ambivalent, or strong belief with respects to the three dimensions of certainty, authority, and subjectivity. On the scale of 1 to 5, a weak belief was defined as a mean score of 1 to 2, indicating a disagreement or strong disagreement to the statements of that scale. A strong belief was defined as a mean score of 4 to 5, indicating agreement or strong agreement to the statements. A moderate/ambivalent belief therefore is represented by a mean score between 2.01 and 3.99 on the scale.

Results

The reliability for the authority and subjectivity scales were found to be good (Cronbach alpha's above .8), while for the certainty scale it was acceptable (above .6). The scree plot and Eigen value from the PCA suggested a three-factor solution that accounted for close to 62% of the total variance. The three factors were extracted using varimax rotation. As seen in Table 3, all items loaded onto the hypothesised dimensions. Focusing on factor loadings more than .3, only item #11 loaded onto more than one factor.

Using the conceptual criteria stringently, most of the participants (67.1%) expressed belief profiles that didn't match any of the predefined categories. Only 27.1% were classified as rationalists and 7.4% as sceptics. Further analysis was done to examine whether more relaxed criteria could better categorise the preservice teachers. This set of criteria (presented in Table 4) identifies a strong belief in authority as the core feature of the dogmatist position, and a strong belief in subjectivity as the core feature of the sceptic position. For these two categories, the other belief dimensions can be either weak *or* moderate (as opposed to having to be weak as in the more stringent criteria). The criteria for the rationalist category were also relaxed, in that it can accept a weak *or* moderate (as opposed to just weak) belief in the certainty dimension. This reduced the size of the "other" category from 65.4% to 14.8% of the sample.

Table 3
Reliability and Factor Structure of the Modified Epistemic Belief Instrument

Items	Dimension & reliability	*Corrected item-total correlation*	*Factor loadings* 1	2	3
1. In science, what is a fact today will be a fact tomorrow.	Certainty *Cronbach's alpha* = .63	.55	.07	- .06	.80
2. Scientists' knowledge of the facts about science does not change.		.37	.23	.17	.61
11(R). In science, what is true today may be considered to be false tomorrow.		.37	.34	- .05	.50
12(R). Scientific knowledge is constantly changing.		.36	- .20	- .10	.67
13(R). Results of scientific research are always tentative.		.30	.28	- .18	.40
7. If a scientist says something is a fact, I believe it.	Authority *Cronbach's alpha* = .88	.71	.84	.04	.08
8. Things written in science textbooks are true.		.65	.84	- .02	.12
9. I believe everything I learn in a science class.		.77	.86	- .22	.03
10. If a science teacher says something is a fact, I believe it.		.87	.90	- .15	.19
3. In science, the truth means different things to different people.	Subjectivity *Cronbach's alpha* = .84	.67	.07	.81	- .11
4. In science, everyone's knowledge can be different because there is no single absolutely right answer.		.67	- .13	.82	.04
5. In science, what's a fact depends upon a person's point of view.		.79	- .20	.89	.06
6(R). Scientific knowledge is all factual and there is no room for opinions.		.55	- .05	.71	- .13

Table 4
Epistemic Belief Categorization Using More Relaxed Criteria

Epistemic belief category	Criterion Certainty belief	Authority belief	Subjectivity belief	Freq.	Percent
Realist	Strong	Strong	Weak	-	-
Dogmatist	Weak to moderate	Strong	Weak to moderate	6	7.4%
Sceptic	Weak to moderate	Weak to moderate	Strong	18	22.2%
Rationalist	Weak to moderate	Moderate	Moderate	45	55.6%
Unclassified	-	-	-	12	14.8%

Discussion

The scales in the modified epistemic belief instrument were found to be more reliable (internally consistent) compared to the original instrument. Furthermore, the PCA showed that all items loaded together onto the hypothesized dimensions. This indicates that the participants could distinguish between meanings of items designed to measure different belief dimensions.

According to a top-down classification approach based on Greene's model, the two biggest epistemic belief categories in the sample resemble the rationalist and the sceptic. Few preservice teachers in the sample resemble the dogmatist, and none resemble the naïve realist. In other words, the quantitative data suggest that the preservice teachers in this study seemed to hold relatively sophisticated beliefs about science. These findings are in line with Kuhn et al.'s (2000) and Hallet et al.'s (2002) theoretical predictions. These findings, however, are inconsistent with the majority of studies on teachers' epistemology of science, which found that both preservice and practicing teachers tend to hold relatively naïve or empiricist/ realist conceptions (Lederman, 1992, 2007).

The application of the strict theory-based criteria to identify epistemic belief positions resulted in a large number of unclassified participants (about two-thirds of the sample). In other words, these individuals' belief scores did not conform to any of the theoretically defined patterns. However, when the criteria were relaxed, most participants' belief profile was found to be meaningful within a modified version of Greene's model. Even among the twelve participants who were still unclassified under the relaxed criteria, the belief patterns were mostly interpretable. For example, no participants expressed a strong belief in the certainty of knowledge coupled with weak beliefs or moderate views in the other two belief dimensions (which would contradict the assertion that epistemic development on the certainty dimension occurs before the other dimensions).

These findings provide partial support to the validity of the modified model and instrument. However, the need to relax the classification criteria may indicate that many participants have yet to form fixed views, or are still undergoing transitions between positions. These possibilities are explored in Study 3 by examining data on participants' response process.

Study 3

Data on how participants respond to a psychological measure provides valuable evidence about the fit between the hypothesized construct and the nature of individuals' actual response or thought processes (AERA, et al., 1999, p. 12). In this study, response process data was collected by asking participants to complete the instrument and then asking them to explain how they understood the items and why chose their responses.

Method

This study addressed these questions (1) How well aligned are the interviewees' interpretation of the items with their intended meanings? and (2) What kinds of epistemic belief profiles or positions do participants express during the interview?

Participants. Participants were six preservice teachers who also participated in Study 2. They were invited to participate during the survey. Participants were rewarded with a movie ticket (worth approximately $12) to take part in this and one other interview (not analyzed for this study).

Interview schedule. The participants were asked to read through the written instrument and explain their responses to one or two items measuring each of the belief dimensions. The main interview question was simply: "Could you explain your thinking behind your response to this statement?" Probing questions include: "What did you mean by ..." and "Could you give some examples?"

Analysis. Content analysis of the interview transcripts was performed. This analysis was guided by the assumption that individuals hold "epistemic resources" or basic ideas about the nature of knowledge that are contextually sensitive (Hammer & Elby, 2002). To make the process more transparent and assist readers in evaluating the credibility of claims, the analytic steps are described in the following (Anfara, Brown, & Mangione, 2002; Patton, 1999).

The first step was to transcribe the interviews in full. I then read all six transcripts to obtain a general sense of information contained in the interviews, and also of the similarities and differences among the participants. Next, I focused on individual transcripts, highlighting and commenting on segments which reflected assumptions about the nature of scientific knowledge. Informed by the multidimensional belief framework (Hofer & Pintrich, 1997) and also the epistemic resource framework (Hammer & Elby, 2002), this initial commentary meant re-describing interview segments in terms of the more specific epistemic dimension that they reflected. In this phase, I looked for similarities and differences with segments from earlier transcripts. This noticing of similarities and differences across (and within) transcripts is similar to the constant-comparative technique described by grounded theory researchers, although the present analysis does not claim to employ grounded theory methodology (Corbin & Strauss, 1990). This sometimes prompted further observations and insights into previously analysed transcripts.

After performing this initial commentary on all six transcripts, I proceeded by writing case descriptions for each participant. The cross-case analysis was mainly based on the individual case descriptions, although at times the transcripts were consulted to re-check the interpretations and claims made in the individual cases. The results sub-section below presents this cross-case analysis.

Results

With regards to the beliefs about the **certainty of knowledge**, all six interviewees said that what counts as valid knowledge in science can change. When asked to explain or elaborate, they discussed this changeability of knowledge in relations to progress in science. Underlying this description of progress is the basic idea or epistemic resource that could be stated as "fallible knowledge" (i.e. the idea that what one believes to be true may turn out to be wrong). For example, when requested to explain her thoughts when responding to the item "In science what is a fact today will be a fact tomorrow", this is what Kate said:

> Kate: "Well, I think that science is dynamic, so, like, constantly changing. I don't really think that anything stays the same. Like, most people thought lots of things in the past and we know that they're not true anymore, or they've changed slightly. Just like you might discover some groundbreaking stuff in your PhD and all the facts about learning science, if that's what its about, would be, like, disproven and false tomorrow."

In elaborating their views about uncertainty, Diana, Henry, Jack, and Kate combined the "fallible knowledge" idea with another epistemic resource that Hammer and Elby (2002) termed "knowledge as direct perception" (i.e. the idea that knowledge can be simply picked up from an objective reality). This is reflected in, for example, Diana's explanation of her responses to the item "Scientists' knowledge of the facts about science does not change":

> Diana: "… a fact being something like the fundamental of what … science is based on. So … uhm, like the beginning of physics, and like the beginning of a lot of sciences, is just to assume, like, things like the earth is round, whereas previously it was that the earth was flat and so much was based on that. Then when that was disproven, then, so much of science was wrong. And so, like, yeah, what was a fact, uhm, was no longer a fact."

In this quote, Diana portrayed factual statements as capable of being disproven. The 'fact' that the earth is flat was regarded as true, but now proven to be false. This suggests that Diana sees change in science in a similar way to the Popperian account: science makes progress through the falsifications or revisions to previously held beliefs. The quote above also indicates that Diana saw factual statements as being fundamental to science. Thus, a fact can become the basis of much scientific knowledge, and when that fact is disproven, "so much of science" can also fall. Here the "disproving" of knowledge is discussed as an intuitively simple and unproblematic process of comparing claims to objective representations of reality.

With regards to beliefs about the **subjectivity of knowledge**, two kinds of account or versions could be distinguished. The first account, expressed by Henry, Elizabeth, and Kate, cites the role of *interpretive frameworks* (e.g. prior knowledge, personal beliefs, etc.) in the construction of scientific knowledge. For example, explaining his interpretation of the item 'In science, the truth means different things to different people,' Henry said that ideally science should be factual, but that in reality "people's opinions are filtered through." In elaborating this point, he drew from the debate between creationists and evolutionary biology:

> Henry: "That argument may never be settled because of uhm the fact that none of us were there. But I think because … I think it sort of does mean there's a bit of bias so for example, uhm, using the same information so uhm, a common example might be sedimentary layers uhm, so for example in the Christian religion uhm, they will […] explain the sedimentary layers and say oh this is evidence of a world wide flood, but the same information that scientists, you could say secular scientists, will look and say, oh on, this sedimentary layer means that uhm, yeah, that over many many years the layers have fallen across each other and stuff like that. So uhm, that was the example I was thinking of. The same information can be interpreted differently, yeah, just interpreted differently."

After the quote above, Henry continued by elaborating two other examples. The first was the differences in interpretations between creationists and scientists on how reliable carbon dating is. The second was about how palaeontologists make inferences about what prehistoric animals look like based on the available evidence. He said that scientists would need to draw analogies with contemporary animals to "sort of reduce the bias [because] there is I guess a subjectivity in trying to see how, what the original animal could look like." These comments clearly show that Henry was aware of the possibility of different interpretations of the same data. In this view of subjectivity, knowledge is to some extent *necessarily* subjective. This account seems to draw from another epistemic resource that

Hammer and Elby (2002) termed "knowledge as fabricated stuff" (i.e. the idea that new knowledge is constructed from previously existing pieces of knowledge).

The second account of subjectivity (expressed by Diana, Jack, & Eve) doesn't refer to interpretive frameworks. Instead, it portrays scientific knowledge is partially subjective, in the sense that different scientists can make competing claims for certain issues. For example, asked to explain why she was ambivalent about items measuring the subjectivity of knowledge, Eve said that scientific knowledge, for the most part, is "straight out clear". However, some parts of it, such as the debate about what caused the dinosaur extinction, may be less objective and in dispute, containing "little opinions". Prompted to elaborate on what makes those parts of science less objective, Eve cited the lack of evidence. In the case of the dinosaurs, she said that there is no single right answer because the event happened millions of years ago, and thus evidence on the event is hard to obtain and there isn't any "clear way for experimenting".

The basic idea underlying this second account of subjectivity was not "knowledge as fabricated stuff", but rather a combination of "fallible knowledge", "knowledge as direct perception," and another resource that may be described as "foundational knowledge". This latter resource refers to the idea that some degree of trusted (but not necessarily correct) knowledge is needed to make decisions and take actions in the world. This idea enables individuals to make sense of statements such as "… but there are better answers and you have to base your science on those … otherwise you don't go anywhere" (from Diana) and "you're not positive but you can be sure enough to base logical thinking on it" (from Jack).

With regards to beliefs about **authority justification**, several accounts could be distinguished. The first was expressed by Diana, whose response to the written instrument indicated a strong belief in authority. She explained her agreement to the item 'If a scientist says something is a fact, I believe it' in the following:

> Diana: "… with science I think – yeah, I just assume that it's true because otherwise you can't move on in science if you don't believe the fundamental facts. Then you just, you can't. So if you don't grasp the small things you can't move on. So if you don't grasp that plants make their own, you know, food and nutrients and stuff, well then you can't move on to understand photosynthesis and you can't move on to understand all the other stuff."

Diana's response could be seen as a way to reconcile her belief about the (un) certainty of scientific knowledge, with her trust towards scientists. She did this by referring to the practicality of doing science: a belief in the fundamental facts of science is necessary to understand natural phenomena. She did not refer to the possibility of scientists making false or wrong claims.

The second account of authority came from Jack and Eve, who expressed ambivalent beliefs about authority in the written instrument. Both Jack and Eve cited the possibility of scientists being wrong, and hence the need for critical evaluation of their claims. For example, this was Jack's comment on why he was ambivalent about the statement on whether scientists' claims about facts can be believed:

> Jack: "Well, you see, before I sat in my science classes, I would have gone 'strongly agree.' But he said that they're constantly learning. He also said that scientists are held to rigorous standards and if they are proven to be liars or their methods are false, they get basically chucked out and they're no longer scientists. […] You're not positive but I suppose you can be sure enough to base logical thinking on it, but you can never truly be positive about anything unless it happened to you and it was something you saw and did."

The first part of the quote above indicates that Jack's ambivalence towards authority was related to the view about the uncertainty of knowledge: if scientists can be wrong, then they cannot always be trusted. The subsequent sentence indicates that Jack saw a possibility of obtaining what he called "real facts" about things that individuals have personal (sensory) experience of. Thus, this account of authority justification is based on the idea of "fallible knowledge" combined with "knowledge as direct perception".

This second account was also expressed by Henry and Kate, who espoused a weak belief in authority in the written instrument. Compared to the others, Henry and Kate seemed to be more sceptical of authority. Henry, for instance, referred to his view about the possibility of change in scientific understanding, saying that textbooks "explain things as best it can up to the day it was published," but could contain knowledge that has since been disproved. This is what Henry said about why he disagreed to the statement on science textbooks:

> Henry: "Oh well, there wasn't too much to my response. There wasn't too much detail. I guess in a sense I have a sort of attitude, I don't want to, like, when something's explained to me then I

Table 5
Summary of Interview Findings

Dimension	Beliefs	Participants
Certainty	The body of scientific knowledge changes in the sense of continually being revised in the face of new evidence.	All participants
Authority	Scientists' claims about scientific facts need to be trusted; otherwise science cannot make progress.	Diana
	Scientists' claims represent current understanding. But those claims can be wrong and hence need to be critically evaluated.	Jack, Eve, Henry, & Kate
	Reality is complex and scientific knowledge is necessarily incomplete. Thus, any claims from scientists are always tentative and partial.	Elizabeth
Subjectivity	For some issues, there is no conclusive data or evidence and hence scientists could have subjective opinions.	Diana, Jack, & Eve
	Scientific knowledge needs to be *inferred* from data, hence to an extent it is necessarily subjective	Henry, Kate, & Elizabeth

have more, like, or more likely to believe it … but the idea of taking something on face value in a textbook, you know, I just don't see it as necessarily a *wise*, or even a scientific thing to do."

Henry and Kate also cited the role of sense making in the evaluation of scientific claims made by authority. This was Kate's comment:

Kate: "… Now that I have a greater knowledge of the world, I don't think I'm going to just accept something, I'd like to know. And most things explain why something is [the case]. Not one often just says this is so, that that's it. There's usually more background information."

This reflects the idea that the believability or trustworthiness of scientific claims depends on how understandable they are. In other words, to evaluate a claim, a person would need to understand and make sense of it. More succinctly, this idea can be expressed as "belief requires comprehension."

The only participant who did not discuss authority justification in terms of scientific progress was Elizabeth. Instead, she explained that because reality is complex, individual scientists or studies are necessarily partial and hence need to be taken with a grain of salt. Here Elizabeth wasn't drawing upon the "knowledge is fallible" idea. Rather, her comment is perhaps better described as reflecting a combination of two ideas: "reality is complex" and "knowledge is incomplete/partial". The former idea is more about the nature of reality, i.e. that reality is more complex than it appears. The latter states that human knowledge about something is typically partial.

Discussion

Participants' explanations of their responses to the epistemic belief items are summarized in Table 5. The findings indicate that the epistemic belief instrument items prompted participants to think about the target constructs. The items in the "certainty" scale were designed assess individuals' beliefs about whether scientific knowledge changes. This was indeed the case. In explaining their responses to these items, all six interviewees expressed the view that scientific knowledge is continually revised in the face of evidence. The notion of certainty or uncertainty of knowledge is not well elaborated in current models of epistemic beliefs. This description enriches descriptions of what "(un) certainty" in science means to individuals (at least, to the preservice teachers in this study).

The items in the "authority justification" scale were designed to assess individuals' beliefs about whether claims coming from authorities in science could be trusted. In line with this, five of the six interviewees reported thinking about the authority of scientists. Diana reported thinking that scientists need to be trusted because their current claims to knowledge are the foundation of scientific progress. Jack, Eve, Henry and Kate expressed a more sceptical stance: claims from scientific authority need to be critically evaluated. This line of thought is consistent with what has been described by current models (Greene, et al., 2010; Hallet, et al., 2002; Kuhn, et al., 2000).

The only exception was Elizabeth, who did not explicitly mention scientists or other authority figures. Rather, her explanation referred to the complexity of the object of science, and the necessarily partial nature of scientific knowledge. Nonetheless, Elizabeth's explanation was indirectly relevant to the issue of authority justification: because no one scientist can claim of having complete or absolute understanding about reality, any claims from authority need to be taken viewed sceptically. This line of thought about authority justification is not commonly reported in current models and descriptions of epistemic beliefs.

The items in the "subjectivity" scale were designed to assess individuals' beliefs about whether scientific knowledge is inferred or constructed through subjective processes, as opposed to be discovered from objective reality. The interview data indicate that participants did indeed think about this issue when responding to the items. Two views could be distinguished. The first view, expressed by Diana, Jack, and Eve, is that scientists' subjective interpretation is necessary when data or evidence is not conclusive. The second view, expressed the Henry, Kate, and Elizabeth, seems to be closer to the notion of relativistic views described by models of epistemological development (Kuhn, et al., 2000). In this view, scientific knowledge is necessarily subjective because it is constructed based on prior knowledge (which is true regardless of the extent of data available).

General Discussion and Conclusion

Three studies were conducted to examine the validity of Greene et al.'s (2010) epistemic belief model and instrument, based on evidence about internal structure and response process. The first study indicated some problems with the "certainty/simplicity" and "subjectivity" dimensions of the model. This is in line with previous evaluations of epistemic belief questionnaires, and underscore the difficulty of measuring constructs related to knowledge (Clarebout, et al., 2001; Debacker, et al., 2008). Based on a close examination of the construct definition and content of the items, a modified model and corresponding instrument were proposed and evaluated further.

The findings of Study 2 indicate that the modified model and instrument were more robust in terms of its internal structure. While only containing few items, the scales measuring "authority" and "subjectivity" belief were found to be reliable. The modified "certainty" scale measuring "certainty" was also found to be more reliable compared to the original, presumably due to the specification of the construct definition (to focus on whether knowledge changes or not). However, more items are probably needed to make the "certainty" scale more reliable. The findings of Study 3, by and large, indicate that the modified instrument does indeed tap into participants' thoughts about the target constructs. Thus, overall these findings support the use of the modified instrument to measure epistemic beliefs – at least for participants at similar levels of development to the preservice teachers in these studies.

However, the interview data in Study 3 show there are variations in epistemic beliefs among participants with similar scores on the written instrument. In the written instrument, five participants registered moderate or ambivalent beliefs about the subjectivity of knowledge. For two participants, this meant that some parts of science are objective while other parts are more subjective. In contrast, for the other three participants, the ambivalent belief was expressed in terms of the inherent subjectivity of scientific knowledge. This could be interpreted as a problem of the limitation of the written instrument in assessing nuances in individuals' beliefs. If this is the case, then new items need to be written which explicitly target these distinct versions of "subjectivity" of knowledge.

Conclusion

Based on these findings, it could be concluded that the modified model and instrument could be used to assess some aspects of epistemological belief among young adults.

Limitations

It is important to mention that the studies are based on a limited sample, particularly in terms of the relative homogeneity of the participants' stage of epistemological development and also cultural context. The modified model and instrument needs to be further validated among individuals from different levels of development. Methodologically, a study conducted on a more heterogeneous sample would benefit from the application of Rasch analysis or item-response theory more generally (Wu & Adams, 2007). Such an approach would enable researchers to evaluate the utility of individual items to measure the beliefs of respondents at different levels of epistemological stages/positions.

References

AERA, APA, & NCME. (1999). *Standards for Educational and Psychological Testing*. Washington: AERA.

Anfara, V. A., Brown, K. M., & Mangione, T. L. (2002). Qualitative analysis on stage: Making the research process more public *Educational Researcher, 31*, 28-38.

Bendixen, L. D., & Feucht, F. (Eds.). (2010). *Personal Epistemology in the Classroom: Theory, Research, and Implications for Practice*. Cambridge: Cambridge University Press.

Bhaskar, R. (1978). *A Realist Theory of Science*. Hassocks, Sussex: Harverster Press.

Clarebout, G., Elen, J., Luyten, L., & Bamps, H. (2001). Assessing epistemological beliefs: Schommer's questionnaire revisited. *Educational Research and Evaluation, 7*(1), 53-77.

Corbin, J., & Strauss, A. (1990). Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology, 13*(1), 3-21.

Debacker, T. K., Crowson, H. M., Beesley, A. D., Thoma, S. J., & Hestevold, N. L. (2008). The challenge of measuring epistemic beliefs: An analysis of three self-report instruments. *The Journal of Experimental Education, 76*(3), 281-312.

Greene, J. A. (2007). A model of the development of epistemic and ontologic cognition. Unpublished doctoral dissertation. University of Maryland.

Greene, J. A., Azevedo, R., & Torney-Purta, J. (2008). Modeling epistemic and ontologic cognition: Philosophical perspectives and methodological directions. *Educational Psychologist, 43*(3), 142-160.

Greene, J. A., Torney-Purta, J., & Azevedo, R. (2010). Empirical evidence regarding relations among a model of epistemic and ontologic cognition, academic performance, and educational level. *Journal of Educational Psychology, 102*(1), 234-255.

Hallet, D., Chandler, M., & Krettenauer, T. (2002). Disentangling the course of epistemic development: parsing knowledge by epistemic content. *New Ideas in Psychology, 20*(2-3), 285-307.

Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal Epistemology: The Psychology of Beliefs about Knowledge and Knowing* (pp. 169-190). Mahwah, NJ: Erlbaum.

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology, 25*(4), 378-405.

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

Hofer, B. K., & Pintrich, P. R. (Eds.). (2002). *Personal Epistemology: The Psychology of Beliefs about Knowledge and Knowing*. Mahwah: New Jersey: Lawrence Erlbaum Associates.

House, E. R. (1991). Realism in research. *Educational Researcher, 20*(6), 2-9.

Kardash, C. M., & Howell, K. L. (2000). Effects of epistemological beliefs and topic-specific beliefs on undergraduates' cognitive and strategic processing of dual-positional text. *Journal of Educational Psychology, 92*, 524-535.

Kitchener, K. S., & King, P. M. (1981). Reflective judgment: Concepts of justification and their relationship to age and education. *Journal of Applied Developmental Research, 2*, 89-116.

Kitcher, P. (2001). *Science, Truth, and Democracy*. Oxford: Oxford University Press.

Kuhn, D. (2000). Metacognitive development. *Current directions in psychological science, 9*(5), 178-181.

Kuhn, D., Cheney, R., & Weinstock, M. (2000). The development of epistemological understanding. *Cognitive Development, 15*(3), 309-328.

Kuhn, D., & Pearsall, S. (2000). Developmental origins of scientific thinking. *Journal of Cognition and Development, 1*(1), 113-129.

Kuhn, D., & Udell, W. (2003). The development of argument skills. *Child Development, 74*(5), 1245-1260.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*(4), 331-359.

Lederman, N. G. (2007). Nature of science: Past, present, and future. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of Research on Science Education* (pp. 831-880). Mahwah, NJ: Lawrence Erlbaum.

Lutz, D. J., & Keil, F. C. (2002). Early understanding of the division of cognitive labor. *Child Development, 73*(4), 1073-1084.

Magolda, M. B. B. (2008). Three elements of self-authorship. *Journal of College Student Development, 49*(4), 269-284.

Magolda, M. B. B., King, P. M., Taylor, K. B., & Wakefield, K. M. (2012). Decreasing authority dependence during the first year of college. *Journal of College Student Development, 53*(3), 418-435.

Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *HSR: Health and Services Research, 34*(5), 1189-1208.

Perry, W. G. (1970/1999). *Forms of Intellectual and Ethical Development in the College Years*. San Fransisco: Jossey-Bass Publishers.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*(3), 498-504.

Schommer, M. (1993). Epistemological development and academic performance among secondary students. *Journal of Educational Psychology*, *85*(3), 406-411.

Schraw, G., Bendixen, L. D., & Dunkle, M. E. (2002). Development and validation of the Epistemic Belief Inventory. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal Epistemology: The Psychology of Beliefs about Knowledge and Knowing* (pp. 103-118). Mahwah, NJ: Erlbaum.

Teo, T. (2013). Examining the psychometric properties of the epistemic belief inventory (EBI). *Journal of Psychoeducational Assessment, 31*(1), 72-79.

Wood, P., & Kardash, C. M. (2002). Critical elements in the design and analysis of studies of epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal Epistemology: The Psychology of Beliefs about Knowledge and Knowing* (pp. 231-260). Mahwah, NJ: Erlbaum.

Wu, M., & Adams, R. (2007). *Applying the Rasch Model to Psycho-social Measurement: A Practical Approach*. Melbourne: Educational Measurement Solutions.