



Personal Epistemology and Sophomore Civil Engineering Students

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Abstract

This paper reports early findings of a larger, longitudinal study on civil engineering students' personal epistemologies. Though much research has been done in exploring student personal epistemologies in general, limited research has been done exploring student beliefs about knowing in the domain of engineering. In this study, ten sophomore-level students participated in multiple, semi-structured interviews throughout a 200-level Statics course. These interviews were analyzed for indications of change in personal epistemologies, using frameworks developed by previous personal epistemology researchers. While many of the interviewed students showed expected progression through these frameworks, others show changes not accounted for in these frameworks. We believe these fluctuations emphasize the need to explore domain-specific epistemologies and call for further research in this area. Based on our findings, we believe engineering education will benefit from a greater understanding of domain-specific personal epistemologies and student progression through established personal epistemology development frameworks. We also believe that further study of changes in students' personal epistemologies is necessary to understand epistemologies of students who do not progress as predicted through these frameworks.

Introduction

Based on research completed by scholars since the 1960's^{1,2,3} it is safe to assume that students' beliefs about knowledge will change over the course of their education. These beliefs are referred to as personal epistemology, and most scholars in the field believe that they can be examined in terms of different subcategories, or dimensions. These dimensions often include how certain we can be about knowledge, where knowledge comes from, how we organize knowledge and how we justify what we know. Though there have been many quantitative, cross-sectional, survey-based studies examining university students' general personal epistemologies^{4,5}, there have been relatively few longitudinal, qualitative studies exploring personal epistemology at the university level. Focusing on the breadth of student experience at a single moment limits the depth of information on students' changing epistemologies. Furthermore, these broad surveys focus on generalized knowledge while leaving issues of domain specificity in epistemology largely unaddressed.

Purpose

The purpose of this paper is to explore a group of sophomore-level civil engineering students' personal epistemologies as part of the results from the first year of a larger longitudinal, qualitative study. In this way, we can explicitly track changes in personal epistemology and identify at what stages in students' academic careers they take place. In this paper, we will explicitly examine changes in students' personal epistemologies over the course of their sophomore year in the civil engineering program. The primary research questions for this paper are:

1. How do civil engineering students' domain-specific personal epistemologies change over their sophomore year in college?

2. How do those changes compare to previous research on changes in student personal epistemology in the general knowledge domain?

First, we will present some background about previous research in personal epistemology and the theoretical framework this study is based on. Then we will present the methods we used to achieve the purpose including a summary of our participant population. Finally, we will present and discuss our results.

Background

Beginning with Perry¹, researchers have been exploring the development of students' beliefs about knowledge and knowing, or personal epistemology. Perry produced foundational research in the field that developed the first theory of student personal epistemology. His theory can be summarized as a set of developmental stages that students progress through as they complete their undergraduate degrees. Following Perry, several researchers have worked to revise his theory of personal epistemology development to address weaknesses in his design as well as explore new avenues of related theories^{2,3,4,6}. Many of these researchers^{1,2,3,5} explained personal epistemology as a set of stages of development. Many of these theorized stages are very similar and build on Perry's original model, so in this paper we will use Perry's developmental framework. This framework can be summarized as four stages which students progress through as under other developmental frameworks (e.g. Piaget, Erikson, etc.):

1. Dualism: In this stage, learners believe that knowledge is either right or wrong and is conveyed to them by an authority that knows the truth. We believe that learners in this stage can perform tasks and processes as dictated to them, but they will not critically evaluate the reasoning behind the process.
2. Multiplicity: In this stage, learners believe that there is an ultimate and absolute truth known by authorities, but some uncertainty may exist in certain areas. We believe that learners in this stage recognize that evaluation of reasoning for some processes may be necessary, but they may not know how to perform those evaluations.
3. Relativism: In this stage, learners believe that knowledge is context dependent, that knowledge is variable relative to the knower, and that the knower participates in the process of making meaning. We believe that learners in this stage recognize the need for and do perform critical evaluations of most reasoning processes, but it is not likely that they can generalize across contexts.
4. Commitment within Relativism: In this stage, learners maintain relativistic beliefs, but also identify and commit to personal beliefs that delineate the nature of truth and knowledge (i.e. identity or values). We believe that learners in this stage are likely able to generalize across contexts and make informed critical judgments about processes of reasoning.

Many personal epistemology researchers view personal epistemology as being composed of beliefs about specific aspects or dimensions of knowledge^{3,7,6}. These dimensions are descriptive traits of a personal epistemology, and these traits are used to determine which stage of Perry's framework¹ an individual falls in. Thus a multiplicitist and a relativist would have beliefs for each dimension, but the differences in those beliefs are the means of distinguishing their epistemological stage of development. Based on the summarized dimensions explicated by Hofer and Pintrich⁶, we have defined a set of dimensions to use in this research. The dimensions

are outlined in Table 1. The dimensions Structure, Certainty, Source, and Justification of Knowledge were defined directly by the dimensions summarized by Hofer and Pintrich⁶. The research group also created the final dimension, Social Processes of Knowing. This dimension was informed by the social constructivist research epistemology that is the foundation for this work (see [8] for an in depth explanation of social constructivism). This dimension refers to individuals' beliefs about the ways in which social processes and communication can affect knowledge.

Table 1. Personal Epistemology Dimensions

Dimension	Explanation
Structure of Knowledge	The ways in which students think about how knowledge is related and organized in a domain.
Certainty of Knowing	The ways in which students think about what knowledge in the domain is certain and how they attribute "truth" to knowledge.
Source of Knowledge	Where students think knowledge in the domain can come from.
Justification of Knowledge	The ways in which students think knowledge in the domain should be evaluated and the criteria for acceptable knowledge.
Social Processes of Knowing	The ways in which students think that different people know and how collective understanding affects knowledge.

In part as a result of the complexity of investigations in personal epistemology, it is important to explicitly define context when addressing beliefs about knowledge and knowing. The domain-specific nature of personal epistemology and the importance of domain specific investigations have been highlighted by several researchers^{9, 6, 5}. In order to address these issues, this research explicitly focuses on participant personal epistemology in the domain of civil engineering, as will be discussed in the methods to follow.

Methods

Participants were selected based on enrollment in a lower-division Statics course. All participants attended the same R1, land grant institution in a rural setting and were recruited near the same time that they certified into the Civil and Environmental Engineering department within the College of Engineering and Architecture. Their interviews were coded using inductive and thematic methods of analysis, and the conversations were then used to identify changes in student epistemological beliefs according to Perry's framework¹.

Participants

Ten sophomore-level civil engineering students participated in this study. Participants were recruited through a sample interview process. Initially, students were contacted via their Statics class. After initial contact, volunteers participated in a sample interview, completed the Statics Concept Inventory¹⁰, and were classified in quartiles based on their Statics grade. During the sample interview students were asked questions about their personal history in order to provide sociocultural background information, they were asked to complete a statics ranking task in order to assess their Statics concept reasoning, and they were asked two questions from

Greene et al.'s Epistemic and Ontological Cognition Questionnaire⁵ to get an initial assessment of their personal epistemology. After the interview, students were asked to complete the Statics Concept Inventory¹⁰ in order to assess their Statics conceptual reasoning. Finally, students' academic success in Statics was assessed based on a reporting of their Statics grade in terms of quartiles. These results are summarized in Table 2.

Based on analysis of these results, participants were selected to provide diversity across their background, conceptual reasoning, conceptual understanding, academic success, and personal epistemology. Diversity across these categories is important because they are indicators of student learning and development, which is inherently tied to personal epistemology^{11, 12}, and serve as an initial indication of some of their personal epistemology beliefs. These data are also commonly collected or could easily be collected in a university setting. Though there is not wide gender diversity, representative of the discipline as a whole, there is diversity across participants' backgrounds especially their previous education, ranging from first-time college students to those working on their second bachelor's degrees. There is also diversity in participants' personal epistemologies resulting from many combinations of beliefs about simple and certain knowledge and personal justification of knowledge. These dimensions came from Greene et al.⁵ and represent a range from (a) students agreeing that knowledge was simple and certain and did not feel they played an important role in justifying their knowledge (weak personal justification) to (b) those that held the radically different belief that knowledge is complex and uncertain and had strong beliefs about personal justification. Participant conceptual understanding and academic success also varied greatly. As a necessity for selection, all of the students had a at least a "C" grade in Statics to ensure that they would continue on to the next class in the program, but we still chose students that ranged from the top 25% of grades in the class to the bottom 25% and who had a variety of apparent conceptual understanding, from one student who scored a 92% on the Statics Concept Inventory¹⁰ to one who scored just over 4%. Participants are referred to by number in order to preserve their confidentiality.

Table 2. Student results from sample interviews

Student	Gender	Previous Education	Simple and Certain Statics Knowledge	Personal Justification ^a	Statics CI	Ranking Task on Beams	Statics Grade ^b
101	Male	Bachelor's	Agree	Weak	33.3%	Correct	4
103	Male	Bachelor's	Disagree	Moderate	41.7 %	Correct	1
104	Male	None	Disagree	Strong	91.7%	Correct	1
105	Male	Transfer	Agree	Moderate	25.0%	Incorrect	2
106	Female	None	Agree	Weak	37.5%	Correct	2
107	Male	None	Agree	Strong	33.3%	Correct	2
108	Male	Associate's	Agree	Weak	16.7%	Correct	4
109	Male	Associate's	Agree	Strong	41.7%	Incorrect	2
110	Male	Transfer	Agree	Weak	4.2%	Incorrect	3
111	Male	Transfer	Agree	Moderate	50.0%	Correct	1

a. Weak = no personal justification, Moderate = some personal justification, Strong = a lot of personal justification

b. Based on quartiles, 1 = top quartile, 4 = bottom quartile; where all participants have greater than passing grades

Interviews

Students have participated in two approximately 40 minute long extensive interviews focused explicitly on personal epistemology. These interviews took place at the end of the Fall 2011 semester, as the students completed Statics, and at the end of the Spring 2012 semester. These interviews were semi-structured in the style of clinical interviews in order to elicit hard to capture beliefs¹³ like those about personal epistemology¹⁴. The interview was designed to elicit student beliefs about knowing through acceptance or rejection of statements of belief that aligned with stages in previously theorized developmental frameworks. Examples of these statements are given in Table 3. The interview statements were developed based on an assessment of related literature in other knowledge domains and with other research methods by a multidisciplinary team of experts in the fields of personal epistemology, student development, qualitative research, and civil engineering. Development of a protocol was necessary for this study in order to address issues of domain specificity not covered by previous research and to fit the qualitative methods utilized. The statements were designed specifically to elicit direct responses about students' domain-specific personal epistemologies. Participants were then asked to explain the reasoning behind the acceptance or rejection of each statement in order to allow them to reflect upon their belief statement. Between the two extensive interviews, students also participated in weekly, 20 to 30 minute check-in interviews. These check-in interviews were loosely structured and focused on personal epistemology as directed by the conversation. This data was used to augment the understanding of student epistemological development beyond the more focused, in-depth interviews at the end of each semester.

Table 3. Example interview questions.

Dimension	Example Question
Structure of Knowledge	The things that I know are mostly unrelated.
Certainty of Knowing	I can never be absolutely certain about the things I know.
Source of Knowledge	The things that I know are mostly things I read or heard from other people.
Justification of Knowledge	When I want to be sure of something I try to find a more knowledgeable source.
Social Processes of Knowing	For most of the things I know it's impossible for someone to disagree.

Analysis

The extensive interviews were professionally transcribed, and extensive notes, as well as audio recordings for reference, were taken during the weekly check-in interviews. Each interview was then initially coded using descriptive or inductive coding techniques¹⁵. During this initial stage, each interview was coded for statements of beliefs about knowledge. Pertinent statements were identified based on the dimensions and stages of personal epistemology development. Codes were developed inductively based on these statements using simple phrasing for consistent application across cases. For example, one code used was "certainty comes from experience." This code was used when participants made statements that implied that one can only be certain about knowledge with extensive experience in that area.

After this stage, the inductive codes were analyzed holistically to identify themes in the data based on thematic analysis¹⁶. These themes helped to identify overall trends in participant responses and identify changes in participant beliefs over time. Each case was analyzed for consistent and repeated use of codes within each interview and across the semester. Consistent and repeated use of codes within each interview resulted in a classification of each student in each dimension from Perry's stages. Based on the consistency and repetition of beliefs statements across the semester, participants were categorized in three distinct categories (detailed below). Consistent, repeated beliefs espoused throughout the semester lead to a classification of 'holding the line.' Beliefs that followed the trend of Perry's developmental framework lead to a classification of 'following the trend.' Beliefs that were neither consistent across the semester nor followed Perry's developmental framework lead to a classification of 'breaking the mold.'

Results and Discussion

Based on the data analysis, changes were identified in seven of the ten participants across the Spring 2012 semester. The seven participants who did demonstrate changes in their personal epistemologies did so in different ways, at different times and to different degrees. Though these changes differed based on participant, they can still be discussed terms of Perry's framework¹ and the defining dimensions. Though the students and quotes presented do not necessarily discuss all dimensions, they were selected as clear, representative examples of the processes of change.

Following the trend

Some participants exhibited changes in their personal epistemologies that followed the developmental frameworks laid out by Perry¹ and others like him. For example, in the Structure of Knowledge dimension, 101 transitioned from beliefs that knowledge is narrow, simple, and organized to beliefs that knowledge is complex and related across multiple disciplines. In the Fall 2011 extensive interview, 101 made comments including "you can apply it [engineering knowledge] to real life right there, it's like practical problems. And could be just facts, yeah, whatever problem we see there, something's going on out there, say that problem's going on out there" and "I mean, yeah, actually I don't think statics is as broad as like physics or <laughs> you know, I mean, physics is broad. I think that [Statics is] based on a few fundamental principles basically." The first quote represents a set of statements in which we can identify this participant's beliefs that engineering knowledge is drawn from and applied to reality exactly with no variation, interpretation, or inconsistencies. The second quote is representative of this participant's statements implying a belief that engineering knowledge is both basic and narrow. These quotes represent Perry's dualist stage by reflecting beliefs in simple, certain, and absolutely accurate knowledge.

On the other hand, in the Spring 2012 extensive interview 101 made comments showing development through Perry's framework:

101: Especially going through school, I mean, I can see [the things I know are] very related. Because first you take one math. When you take the second math, you apply that to the next one [implying that knowledge is related but distinct]. Or I think this semester I was talking about certain things that I learn in physics, I'm applying it to even statics, or

what I do in statics-- for example, vectors. I mean, statics, you see vectors. And then you see vectors in calculus, you see vectors in physics [implying that knowledge does not lie in discrete categories]. So on and on. So once you learn the basic thing [implying an initial belief of a dualist perspective], and then you keep applying it and relating everything together [implying growth to a more relativist perspective].

In this quote, we can see statements that imply that this participant believes that knowledge is related across courses. There are also statements implying that knowledge is not separated into discrete categories based on disciplinary boundaries. The final statement in this quote represents his transition from the belief that knowledge is simple to the belief that knowledge is more complex and interrelated. This transition from beliefs that knowledge is simple and organized to beliefs that knowledge is complex and interrelated is reflective of a transition from a dualist perspective to a more multiplicitist or relativist perspective.

Holding the line

Despite identifying changes in many participants, some participants experienced no apparent change in their personal epistemology or did not exhibit changes within specific dimensions. For example, in the Justification of Knowledge dimension, 104 consistently demonstrated the belief that knowledge should be justified through an examination of reality or the real world. In the Fall 2011 extensive interview, 104 made comments indicating that all engineering knowledge can be justified by comparing it to an objective reality:

104: A lot of the stuff we've come up with is just experimental like the static friction stuff <laughs>. That's what's standing out in my head right now. And-- yeah. Pretty much all that stuff was determined by experimentation at one time or another. So that's usually how you prove your math is right, you check it with real stuff.

In the Spring 2012 extensive interview, 104 continued to emphasize justification of knowledge through empirical observation:

104: When I want to be sure of something I check to see how it fits with reality. Well yeah, of course you're going to do that. I wouldn't want to just check it with a theory. I mean you can look at your equations and stuff. It can look perfectly fine, but if you think about the answers then maybe they're not fine.

This consistent reference to checking or justifying knowledge through objective reality is representative of a dualist perspective, rather than a forward progression through the developmental framework.

Breaking the mold

Some of the participants that experienced change in their beliefs did not do so in ways that typified Perry's developmental framework¹. For example, in the Social Processes of Knowing dimension, 108 transitioned from beliefs that knowledge is developed over time through the accumulation of many people's experiences and consensus, to beliefs that knowledge is objective and absolute. In the Fall 2011 extensive interview, 108 made comments implying that knowledge within a discipline is based on experience and wide spread agreement and interpretations of those experiences:

108: I feel like statics is kind of a time-tested thing where it's like-- it's been around long enough that there's-- a lot of people agree on it and it's kind of like a set, you know, thing

and if one person comes out with some crazy, new theory or view on it then it's not necessarily right. I mean, it could be, but it's not like automatically just "Yeah, that's right, good job."

In the Spring 2012 extensive interview, 108 places greater value on empirical observation of an objective reality, rather than accumulation of knowledge through experience and consensus:

108: I feel like it's hard to have an opinion about a lot of the stuff that we do in class and stuff because there's kind of, like, you know, it's not English class where people can have, like, different opinions about it, like, oh, I thought it meant this or I thought it meant this. It's kind of, like, well, you know, when you're calculating beam deflection, it's, like, this is how much it bends or something

This transition from beliefs that knowledge is considered certain through a consensus of experts to beliefs that knowledge is objective and opinion-less is reflective of a transition from a relativist perspective to a dualist perspective. This conflicts with previous theories by showing an apparent transition from a more highly developed stage in Perry's framework to a more naïve perspective.

Conclusion

Limitations

It should be noted that this study's general design has several common limitations. Because this study is qualitative in nature it is difficult to have a large sample size, which limits generalizability of the study and would make it impossible to determine statistical significance. Within qualitative research though, we can and have implemented within-case, purposive sampling¹⁵ in order to provide a theory driven sample, which provides richness to the data that ensures depth of understanding. We have done this by purposefully selecting a stratified group of students from the same case, i.e. students had diverse backgrounds, beliefs, and understanding upon selection and were chosen from the same academic level, course, program, and institution.

Another limitation in the general design of this study is the short time period over which data were collected. Data collection only occurred over a period of approximately 16 weeks, or one semester, which may make it difficult to identify lasting change in personal epistemology. Though this limitation is not being addressed in this particular paper, these results are only preliminary as part of an ongoing longitudinal study. Students will continue to participate through graduation from their undergraduate program. As a result, we can continue to track changes in their personal epistemology and refine our conclusions as the study progresses.

A third limitation that we have identified in the general design of this study is that apparent changes in participant personal epistemology may simply be temporary fluctuations in belief with no permanent change effected. There is limited prior research on the extent to which students will experience fluctuations in personal epistemology and no previous work on identifying the impact of those fluctuations. We have attempted to address this limitation in two ways. The first is to increase the length of time of the study. Continued longitudinal data collection will allow us to see if these changes continue to be apparent as participants progress through their program. The second is to increase the resolution of the study. Beyond simply

interviewing students each semester, students participate in short interviews each week, which provides finer resolution to the data and shows a trend of change in student beliefs.

Implications

Once these limitations have been addressed, larger implications for student learning come to the forefront. Perry and others have theorized that most students begin college in the dualist stage (or similar) of personal epistemology^{1,2,3}. Based on the data, this theory is supported. Most of these participants displayed dualist beliefs in at least one of the dimensions of personal epistemology at this early stage in their program. Even the students who held previous degrees (i.e. a Bachelor's or Associate's degree in another field) verbalized some level of dualist belief. Though these students may hold more mature beliefs in the field their degree was obtained in, it is likely that the domain specific nature of personal epistemology necessitates growth from naïve to mature beliefs in the specific domain of Civil Engineering.

Based on this finding, engineering educators should consider that, regardless of background, students likely come into their engineering program with dualist beliefs about knowledge. These dualist beliefs likely constrain students' recognition of the necessity for and their ability to perform critical evaluation of the reasoning for the processes and tasks they are taught to use. Given our findings, as well as those of previous researchers^{1,2,3}, it seems that students are able to independently progress through these stages of belief as they progress through their academic program. At the same time, it is important for engineering educators to recognize students' limited abilities to perform or recognize the need for critical evaluation. Curricula should be designed with this framework in mind to scaffold learning so that students are encouraged to progress through these stages of personal epistemology and so that students are explicitly taught the criteria for evaluation of knowledge that are used in their engineering disciplines.

Future Research

Based on these findings, it appears that that engineering students' personal epistemologies will continue to evolve in major ways throughout their pursuit of an engineering degree. This is consistent with previous researchers' theories of personal epistemology development in students^{1,2,3}. These results show a significant shift in student thought, but this shift may not always fit with epistemological development as predicted by these pre-established development theories of knowledge and knowing. These results do provide continued support for looking at personal epistemology development specifically within the domain of engineering. Furthermore, it is possible that student development within this specific domain may not adhere to that theorized for a more generalized domain of knowledge and may provide grounds for developing an engineering-specific theory of personal epistemology development. Continued research in this area, specifically the continuation of this longitudinal study, will reveal how consistent these results continue to be in relation to theories of personal epistemology development throughout a Civil Engineering program.

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