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How Architecture and Engineering Students Conceptualize Design Creation: Report of a Pilot Study

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How architecture and engineering students conceptualize design creation: Report of a pilot study

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Abstract

This study uses phenomenographic research methodologies to identify qualitatively different ways engineering and architecture students conceptualize design creation; it seeks to discover if and how their conceptualizations of design creation relate to their conceptualizations of knowledge generation. This work extends prior research by King and Kitchener (1994) and others (Baxter Magolda, 1992; Belenky, Clinchy, Goldberger, & Tarule, 1986; Hofer & Pintrich, 2002; Perry, 1970) about the ways students develop increasingly sophisticated ways of: understanding and conceptualizing knowledge; sources of truth; how to evaluate various opinions and points-of-view; and ways to assess truthfulness and validity of new ideas. This project stems from the proposition that this development process manifests itself somewhat differently in fields that deal with physical sciences than in those grounded in the social sciences—the realm where these theories were established and defined. King and Kitchener (1994) have shown that conceptualizations of knowledge vary from one field to the next, yet little if any work has been done to assess and compare patterns of conceptualizations in the fields of architecture and engineering.

Many national regulatory boards urge engineering to change its educational practices to elicit high levels of student engagement and self-directed learning, and achieve outputs more like those associated with architectural education. An extensive report by the Carnegie Foundation for the Advancement of Teaching (Boyer and Mitgang, 1996) was conducted on behalf of the five organizations regulating the education and practice of architecture in the USA. That report described very high levels of student learning and engagement and recommended that the methods used to teach architecture be transferred for use in more fields. The current study provides additional understanding of this topic, identifying the various concepts that architecture students hold about knowledge and design as well as how these conceptualizations are both similar and different to engineering students' conceptualizations. An outcome of this study is increased understanding about aspects of the learning experience and the learning environment that capture students' attention and elicit their engagement. With this knowledge, educators can do more to encourage reflection, exploration, and self-directed learning among students.

This is a work in progress, and the first phase has been a pilot study. This paper reports results of the pilot as well as the context, rationale, and design of the overall study. The pilot was the first step in a study seeking to provide new understandings: (1) spanning multiple professions; (2) identifying the various concepts that architecture and engineering students hold about the generation of new designs; and (3) describing how these conceptualizations compare within and between fields. The second phase will use phenomenographic methodologies to identify qualitatively different ways engineering and architecture students conceptualize knowledge and design. To date, the study has been designed and has gained approval to proceed from our ethics review board. Three pilot interviews have been conducted and these have been used to

adjust the research design and widen the parameters for the sample group. The research team secured ethics approval for the proposed changes. This paper describes the overall design of the study and what was learned from the pilot interviews.

Introduction

How do students interpret the act of creation and how does their understanding change over time? We aim to understand students' experiences of design in civil engineering and architecture. We want to understand how students interpret creating, and we want to use our new understanding in the process of improving pedagogy. Thus, the work described in this paper seeks to provide new understandings: (1) spanning multiple professions; (2) identifying the various concepts that architecture and civil engineering students hold about the generation of new designs; and (3) describing how these conceptualizations compare within and between fields.

This is a work in progress. Our first phase of study has been to run a pilot. To date, we have designed the study, gained approval to proceed from our ethics review board, collected three pilot interviews, revised the study design and protocols, requested and received ethics approval to expand the sample group in repose to findings of the pilot. In this paper we report the context, rationale, and design of the overall study, as well as results of our pilot test. The overall study will use phenomenography to identify qualitatively different ways engineering and architecture students conceptualize design creation; we also seek to discover if and how their conceptualizations of design creation relate to their conceptualizations of knowledge generation.

At the culmination of the overall project, we hope to have contributed new understanding about aspects of the learning experience and the learning environment that capture students' attention and elicit their engagement—to help engineering and architecture educators create learning environments that encourage reflection, exploration, and self-directed learning by students. Thus, the project is about creating learning captivating and engaging environments that ultimately help students go deeper/further in their ability to design and create new knowledge. We hope this preliminary report will be helpful to educators wishing to promote student development. We believe this paper can also be useful to engineering education researchers learning to conduct interviews using a phenomenographic approach, as we describe at the end of this paper.

Theories on Student Development

A group of theories bridging these topics deals with epistemological development (or epistemic cognition). Epistemology is the study of how an individual conceptualizes knowledge, where knowledge comes from, and how it originates. We ground our study—design, data collection, and analysis—using existing theories on epistemological development that describe patterns of change typical among students in and soon after university. Students with sophisticated epistemic cognition consider multiple points of view; they make decisions in context and recognize their own ability to create new solutions and generate new knowledge (Belenky, Clinchy, Goldberger, & Tarule, 1986; King & Kitchener, 1994; Love & Guthrie, 1999; Perry, 1970). This is because architecture and civil engineering students are actively engaged in generating new designs but are, based on our experience teaching, unlikely to bring up 'generating knowledge' as this concept is not commonly discussed in their curriculum. Discussion within these groups typically centers on the design of objects or infrastructure systems. Among architecture students and teacher, everyday

conversations encompass theories new and old, and discussions regarding how to achieve 'beauty,' maintain 'authenticity,' and uphold 'truth.' We suspect this is not the case among civil engineering students, though we believe they will freely discuss creating new designs, objects, and systems.

In 1970, Perry first posited his schema, a framework regarding how students develop intellectually and epistemically, as a result of qualitative studies with university students. These theories have been expanded upon over the years to include increasingly diverse groups of participants. While Perry interviewed male Harvard students in the 1960s, others have interviewed women in, as well as before and beyond, university (Belenky, et al, 1986) and identified patterns typically varying by gender (Baxter Magolda, 1992). Researchers have continued to develop ideas about personal epistemology (Hofer & Pintrich, 2002), sometimes focusing on the specific component of 'reflective judgment' (King & Kitchener, 1994). Regardless of the adaptations, Perry's overall organizational structure—which is essentially a nine-stage model with three major phases of development—still underlies most subsequent theories (Love & Guthrie, 1999). In most of these theories, students are seen to move from: (1) dualist right-wrong thinking, to (2) developing ability to acknowledge and consider multiple points-of view, into (3) relativism wherein they can assess inter-related aspects and effectively make decisions in context. Reaching this advanced stage generally requires the student to make a conceptual breakthrough that Perry calls "Revolutionary Restructuring." Research on epistemic cognition flourishes today with new handbooks (Greene, Sandoval, & Bråten, 2016), incorporation of added disciplinary perspectives (e.g., philosophy and psychology, as per Chinn, Buckland, & Samarapungavan, 2011), and topics (e.g., plausibility judgments, as per Lombardi, Nussbaum, & Sinatra, 2016).

As a whole, this body of research shows students who achieve Revolutionary Restructuring and can restructure their thinking—to be more contextual, trans-categorical, and generative—get more out of their higher education and are much better prepared for their careers than those who do not (Love & Guthrie, 1999). This conceptual shift is necessary for effective performance in STEM, yet the typical engineering student progresses fewer than two positions along Perry's nine-position scheme in college (Pavelich & Moore, 1996).

Research has been conducted to understand how these theories play out across various judgment domains (e.g., "personal taste, aesthetic, value, and truth" as per Kuhn, Cheney, & Weinstock, 2000, p. 309) as well as different fields of knowledge such as science (Elby, Macrander, & Hammer, 2016), engineering (Christensen et al, 2015), and design (Eastman, McCracken, & Newstetter, 2001; Crismond & Adams, 2012).

Ours is the first study we know of to look at students' conceptualizations of design creation, a phenomenon at the heart of architecture and civil engineering. We believe architecture and civil engineering students will share some ideas about design, innovation and newness. We look forward to learning more about what students in these professions make of "knowledge generation" and "the creation of new knowledge," concepts well known in social sciences but uncommon in built-environment professions. Thus, in this study, we investigate how social-science theories play out in built-environment professions that rely on physical science as, for example, a means to protect the health, safety, and welfare of the public these professions serve.

Rationale for Study

Many national regulatory boards urge engineering to change its educational practices to elicit higher levels of student engagement and self-directed learning (Association of American Universities, 2017; Engineers Ireland, 2013; King, 2008; National Academy of Sciences, 2004; National Science Board, 2007). Bourn and Neal (2008) details how regulatory boards in the UK have embraced these values. They describe British aim for engineering education to move away from pedagogies wherein students are "Absorbing information, reproducing received knowledge and accepting and adapting to existing structures and models of thinking, knowing and being" and moving toward pedagogies wherein students are "Assessing, interrogating and connecting information, generating knowledge, living with difference and conflict and shifting positions and perspectives according to contexts" (p. 11).

Architecture courses are seen to consistently develop high level abilities and skills in critical thinking that are consistent with high-level epistemic cognition; in the USA, an extensive report by the Carnegie Foundation for the Advancement of Teaching (Boyer and Mitgang, 1996), conducted on behalf of the five organizations regulating the education and practice of architecture in the USA, described very high levels of student learning and engagement. Boyer and Mitgang recommended that methods used to teach architecture be transferred for use in more fields. Research in this area continues with, for example, Salama (2015) comparing traditional architectural pedagogies with newer alternatives. Practices and pedagogies used in architectural education today have a long, well-established history dating back to the 1500s Renaissance apprenticeship model, but also incorporating (1) aspects of as the charette and jury codified circa 1890 with the Ecole des Beaux-Arts with (2) diverse hands-on maker workshops from the Bauhaus from the first half of the 20th century. Salama (2015, p. xxii) assesses traditional approaches with 'pioneering' new 'alternative' practices for teaching studio. Such practices can include various review formats (Seymour & Chance, 2010) developed to address concerns voiced by Anthony (1991) regarding drawbacks of the jury system. Boyer and Mitgang (1996) also identity drawbacks of architecture culture ranging from undervaluing time and overworking to the point of exhaustion to the subjective and pedantic nature of the jury system. Nevertheless, students are passionately engaged, committed to learning, investigating, and creating.

We intend for this work to extend research by King and Kitchener (1994) and others (Baxter Magolda, 1992; Belenky et al, 1986; Hofer & Pintrich, 2002; Perry, 1970) about how students: (1) develop increasingly sophisticated ways of understanding and conceptualizing knowledge; (2) evaluate various opinions and points-of-view; and (3) assess the truthfulness and validity of new ideas. King and Kitchener (1994) have shown that conceptualizations of knowledge vary from one field to the next, yet little work has been done to assess and compare patterns of conceptualizations in the fields of architecture and engineering. Although social scientists developed and defined the foundational theories (and the concepts seem to fit well within those fields), this process manifests itself somewhat differently in fields that deal with physical sciences (Christensen et al, 2015). King and Kitchener (1994) have shown that conceptualizations of knowledge vary from one field to the next, yet little if any work has been done to assess and compare patterns of conceptualizations in the fields of architecture and engineering.

Drawing from personal observation and the research identified above, the authors of this study believe that the types of abilities desired by regulatory board in the UK, Ireland, and the USA are

consistently evident among graduates of architecture programs in these same countries. They have undertaken this study believing that society can benefit when outcomes of engineering education are more like the outcomes achieved today in architectural education (Boyer and Mitgang, 1996).

Context of the Research

This paper reports our preliminary work designing a study and conducting pilot interviews on *Ways architecture and engineering students conceptualize design creation*. This constitutes our first step in a study that aims to identify the *Qualitatively different ways students of the built environment experience and understand the phenomena of creating something entirely new*.

As our project is currently framed, we will adopt a phenomenographic research methodology to qualitatively identify different ways in which engineering and architecture students experience and understand knowledge and design. We believe that benefits will accrue at multiple levels:

- The individuals who participate can gain by (1) aiding scientific discovery and (2) having enriching discussion related to their fields of study.
- Our institution will gain new understandings of how engineering and architecture students learn.
- Society and the wider public can gain through better understanding of how students learn and develop sophisticated understandings of knowledge creation and design.

Methodology

The current paper reports observations and realizations made through conducting pilot interviews with three university students enrolled at a campus across the city from ours. To prepare for the interviews, we enlisted the assistance and expertise of the second author who provided our research team with multiple training sessions on the theory and practices of phenomenographic interviews and data analysis. To help us master interview techniques required for sound phenomenography, he provided bespoke advice on interview protocol and held the pilot interviews in tandem with two of our research team members. Dr. Mimininis conducted the first and second pilot interview so that we could observe, and the lead author conducted the third interview. Dr. Mimininis observed and provided verbal and written feedback to help us improve our interview techniques.

In this report of the pilot study, we conducted peer debriefings of the pilot interviews, transcribed and conducted a straightforward thematic review of the most relevant interview, and modified our plan and protocols in response. These results are reported below.

In the subsequent/upcoming study, we will use phenomenographic methodologies consistent with established methods of phenomenography (Åkerlind, 2012; Marton, 1986; Marton & Booth, 1997) to inform analysis and interpretation. We will seek to report dimensions of variation in the understanding of the phenomena. These are dimensions of the educational reality present in all conceptions but with different content in each one of them. Thus, we will use phenomenographic research methodologies to qualitatively identify different ways engineering and architecture students conceptualize knowledge creation and design.

Framework

Chinn, Buckland, and Samarapungavan (2011) developed "a philosophically grounded framework for epistemic cognition" (p. 141) comprised of five elements:

1) Epistemic aims and epistemic value
2) The structure of knowledge and other epistemic achievements
3) The sources and justification of knowledge and other epistemic achievements, and the related epistemic stances
4) Epistemic virtues and vices
5) Reliable and unreliable processes for achieving epistemic aims

This study primarily focuses on element #3, looking at "sources and justification of knowledge and other epistemic achievements," described by architecture and civil engineering students, and considering "the related epistemic stances" that correspond with these. In doing this, we will also be seeking to ascertain points of agreement and divergence from existing models on epistemic cognition among and between the sample groups.

Sample

The pilot interviews, conducted at an institution other than our own, lasted 30-40 minutes each and. They were collected from one fourth-year architecture student and two doctoral students who hold undergraduate engineering degrees and have also worked in engineering (one in mechanical engineering and one in petroleum engineering). Our aim in conducting the sample interviews was to test our questions and interview protocols; we wanted to understand how students would react to these and to ascertain the quality and range of insights future participants could be expected to share.

For the larger study, we aim to secure a sample group of 20 students—half from civil engineering and half from architecture. We originally aimed to include 10 fourth-year architecture and 10 fourth-year engineering students, all from one institution in the UK. Based on feedback from peer reviewers, our expert advisor, and the pilot interviews, we have decided to expand the sample group to help us achieve the widest possible range of variation in perspectives. Based on this groundwork, we have now gained ethics approval to collect data from 10 architecture and 10 civil engineering students at second year as well as fourth year of the first professional degree and from three different institutions in the UK and Ireland.

We originally proposed to collect data regarding participants' gender, age, country of birth, number of years in the country of current residence, number of years in tertiary education, and title of their degree program. Our main goal in considering these demographic features, however, is to obtain maximum variation in responses. As such, we may consider these aspects when identifying individuals to invite for interviews. We have considered other ways to ensure variation in the ways students experience the phenomenon as well, such as a brief screening questionnaire to identify suitable participants. In the end, we have chosen to seek individuals with more diverse 'treatment' levels (second- and fourth-year) and teacher influence (at three different sites). After collecting early interviews, we will assess whether or not be are achieving sufficient diversity or if new strategies are needed to increase range of perspectives shared.

Research questions

The research questions for the overall study are: *In what qualitatively different ways do engineering and architecture students conceptualize design creation? How do these conceptions relate to these students' conceptions of knowledge creation?* In assessing these, we will consider sub-questions including: *How do architecture students conceptualize knowledge and design? How do civil engineering students conceptualize knowledge and design? What field-specific pedagogies or values do participants associate with their perceptions?*

The questions driving the pilot study were: *To what degree do the draft interview questions yield data addressing the research questions? How should the interview questions be adjusted to focus on pertinent phenomena? How should the interview protocols be adjusted to support validity using phenomenographic methoodologies?*

Interview questions

Our pilot interviews implemented interview techniques for eliciting maximum variation in responses (Ashwin, 2006). We began by asking participants to "think of a time when you created something entirely new." We proceeded to say, "Now that you have thought of an instance where you experienced this phenomenon of creating something entirely new, we invite you to describe what happened." However, the interviewer new to phenomenography actually followed the principles of phenomenology by probing participants' experience of the phenomenon (design creation) using a semi-structured, dialogical approach. This did not work as well as the experienced researcher's (second author's) techniques and as a result we will follow a more structured interview guide for future interviews, to be collected by the first and third author of this pilot study.

Conversations continued on with probing questions such as: "Is it possible to generate something entirely new? If so, when have you experienced generating something entirely new?" We were prepared to prompt "This might include inventing new systems or objects, developing new designs, or generating new knowledge." During the course of each pilot interview, we asked each participant's thoughts regarding:

- Design and/or the design process
- The role of problem-solving in the participant's studies
- The participant's own ability to invent or author new things
- The participant's own ability to generate new knowledge

Data analysis

As stated above, the pilot study involved a quick thematic analysis of one interview, transcribed in full by the lead author. For the future study, we will have all interviews transcribed by a professional transcription service and our research team will analyze the data (1) using NVivo software for managing data and (2) implementing phenomenographic methods. We will conduct analysis as a team. At least two members of our team will be extensively involved in analyzing data (the lead author, the phenomenographic expert, and possibly the third author). Another two members of our team will serve as validators of the analysis of the data (as recommended by Mimininiris, 2019).

Results and Discussion of the Pilot Study

The most important results of our pilot interviews have been: (1) discovering insightful perspectives and narratives provided by all three pilot participants, leading us to believe that subsequent interviews will provide data useful to answering our research questions; (2) leading us to expand our target sample group to ensure we achieve maximum variation in perspectives; and (3) helping the members of the research team who are new to phenomenography to refine their interview techniques.

With regard to this third point, advice provided by our phenomenographic expert may be of help to others seeking to conduct phenomenographic interviews. Based on observation of the pilot interview conducted by the lead researcher, the expert advised the following:

- Ask very direct "Why, What, How" questions. Simple easy-to-understand questions are best. Avoid making the interview conversational as the actual question tends to get lost or become unclear.
- In contrast to other forms of interview, we need to develop an interview protocol with fixed questions and fixed order.
- In asking questions, you want them to identify their intentions (ask, e.g., "What were you trying to achieve there?").
- In asking questions, you are looking for differences and similarities (e.g., "How is that different/similar to what you said before?").
- Avoid characterizing what you think they have said (a method used in other forms of social science research, such as grounded theory and phenomenology, where it is used to confirm the interviewer's interpretation matched the speaker's intended meaning). Wasting interview time analyzing their responses means you don't spend enough time asking them to shed additional light onto meanings. Spend the time probing the "What, When, Why, and How" of what they have just said, and the differences and similarities to other things they have said.
- Avoid anything that could seem leading (e.g., "That sounds good.").
- Consider using the question "How did you know the results were accurate (or useful)?".
- Make sure the questions are covering the "new" aspect of "creating something entirely new" and/or the "generation of new knowledge."
- Closing questions should ask them to summarize their definitions and/or understandings of the central phenomenon.

The resulting interview protocol is provided as Appendix A. Ultimately, the use of phenomenographic research methodologies will help us identify qualitatively different ways these two groups of students conceptualize knowledge and design. However, based on the pilot interviews, we have reason to believe that participants will provide insight on topics that include:

Invention – Do engineering and architecture students think it is it possible to generate something entirely new? When and how have they experienced generating something entirely new—such as inventing new systems or objects, developing new designs, or generating new knowledge?

Our architecture pilot interviewee indicated invention happens in "*near enough every project… I think every concept that we do in studio is something new that hasn't been done before. I think we've been taught to think outside the box and then just do something that no one's done before.*" And, "*I think every project I did, like I said to you, is a new invention for me. It's not a new invention like an invention that has never been built before. It's a new invention in terms of design. So what else? I don't know. I think every building that you design is a new invention because obviously you don't copy and paste the same building.*" And, "*So I think every single building that I design is new, but it's not new in terms of like it's never been made before. It's new in terms of the way it looks, what it does. But the way I got there is the same. That has been the same process for thousands of years. So still the research, still the site analysis, etc. So all of that is the same. But the actual final outcome -- so the way the building looks, and the way it's used -- that's the new invention.*"

Self-authorship and locus of control – Do participants describe feeling that they have control over outcomes and over their futures?

The pilot interview touched on this, but not explicitly: "*So, for example, when you design a building, a lot of people will tell you ,'Oh, I don't like this because of that.' Or some would say, 'I like this, because of this.' But because there's so many different opinions in this world, like everyone can say a different thing. I think it's up to the designer to choose which of these opinions are relevant. So for example, if somebody says, 'this building, it's too tall.' Yes, maybe it's too tall, but maybe has a purpose why it has to be this tall.*" And, "*So there has to be a limit where you say, 'Right enough, stop. This is my project and this is why I'm proposing to you.' So obviously people have different opinions, no matter what you do. Even if you do change it, they might go back and just—go back to what you said in the first place. So I think as an architect you need to be quite confident with what you proposed to that person.*"

Origins or sources of truth – Do participants reveal who they think defines what is "true" and/or how authorities come to agree on what is "right" or "true"?

An interviewee explained, "*at the time of when you're actually doing the project, you don't know that you you're doing it correctly. It's actually with time that you look back and you're like 'actually that person was saying the truth.' So taking that opinion on board kind of shapes the way you think. [And how do you understand truth? What constitutes truth in your context?] I think it's, you come to realization that, what that person is saying, it could be, could be correct.*" And, "*It's just that as a designer, you have to be able to identify what the key features of your project really are. Like you can't just let everybody just kind of like a pick and choose what they like and dislike. Because at the end of the day, [it] would become their project, rather than your project.*"

Definition of beauty – Do participants reveal who they think defines "beauty" and/or how authorities come to agree on what is "beautiful"? As noted earlier, we believe this topic is likely to arise in discussion with students of architecture, but not civil engineering.

The word "beautiful" was introduced by the interviewee, and then re-visited by the interviewer: "*I think design is, a good design building, is something that will be useful to the user, and it will look stunning. It will be beautiful. And I think it's something about, it has to fit with the*

environment. It can just be something um, out of, out of this world. It has to be something that people will look at and will appreciate, and will appreciate the designer for it."

Establishing validity of new ideas – How have participants evaluated various design options/possibilities? How have they evaluated various opinions and points-of-view? What methods do they use to assess truthfulness and validity of new ideas?

"*I think then you have to go kind of -- kind of go and do the research. Also most of the time, for example, you maybe, at the back of your head, you know these comments yourself, but you don't realize them until somebody points it out. So it's happened. It's up until this point that 'Oh actually that person might be correct.' So because sometimes when you're in – you're designing – you kind of forget the, like the world, around you. And you and, I don't know, maybe just don't think about the logic things and if somebody comes and points it out then you, then you might question it. And that's when you go back, on your design. And that's when you answer the question, if it's actually if it's true, or not, what that person is saying. And maybe you do more research. So it's all about the research to be honest.*"

Knowledge and knowing – Do participants indicate it is possible to know something for certain? Do they indicate what is the role of knowledge in their work and/or their field? Do they describe any processes for coming to know something?

The statement above, listed under invention, is also relevant here. "*So I think every single building that I design is new, but it's not new in terms of like it's never been made before. It's new in terms of the way it looks, what it does. But the way I got there is the same. That has been the same process for thousands of years. So still the research, still the site analysis, etc. So all of that is the same. But the actual final outcome – so the way the building looks, and the way it's used – that's the new invention.*"

Conclusion

This pilot study has shown that a phenomenographic approach can yield results of value to teacher/practitioners and curriculum developers as well as education researcher/theorists who are continually seeking to extend and refine theories stemming from Perry (1970). In this pilot study, collection of interviews has led to a revision of sample group as well as the interview questions and protocols. Lessons learned about differences in interviewer styles highlighted the need to develop an interview protocol with fixed questions and fixed order, helping interviewees describe their intentions and expand the detail they provide to help uncover meanings during analysis. It is essential to probe the "What, When, Why, and How" behind participants' initial statements and ask them to describe differences and similarities among their own statements.

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Appendix A: Interview Protocol

The resulting interview protocol has been informed by:

1. The research team's discussions about the study.
2. Our intent to maintain an open spirit about possible emerging themes.
3. Our focus on pedagogy in the process of creating something new and generating new knowledge.
4. How the pilot interviews unfolded and the discussions we had on the day.

Interview Protocol

Introduction of the interviewer; explain purpose of the study & potential benefit. Give consent form, remind of confidentiality, anonymity, right of withdrawal, compliance with legal provisions and the transcription process.

Questions

1. Thinking of your time here at the University, can you think of a time when you created something entirely new?

   Probe any of the following, as appropriate:
   -Why did you do that?
   -What do you think you were trying to achieve there?
   -Why do you think your organised your work/effort that way?
   -How did you see yourself in this process?

2. Based on your experiences as a student so far, can you think of an occasion where you generated new knowledge?

Probe any of the following, as appropriate:
-Why did you do that?
-What do you think you were trying to achieve there?
-Why do you think your organised your work/effort that way?
-How did you see yourself in this process?

3. You mentioned earlier that you… [*refer to a teaching instance they have already mentioned with regards to the involvement of a teacher/peer in creating something new or generating new knowledge*]. What do you think their role on this occasion was?

   -What do you think they did it that way?
   -How did you see yourself in this process?

4. Do you have any other examples of creating something entirely new?

   Probe any of the following, as appropriate:
   -How did the student/teacher/university go about that?
   -Why do you think they taught it that way?
   -What makes you say that you have achieved something important there?

5. Do you have any other examples of generating new knowledge?

6. Before we conclude, is there anything you would like to add that you haven't had a chance to talk about.

   Probe: Is there anything else you'd like to say, for example, about ….