# AC 2007-1659: DEVELOPING AN UNDERSTANDING OF INSTRUCTORS' DESIGN LEARNING PHILOSOPHIES IN A SERVICE-LEARNING CONTEXT

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# Developing an Understanding of Instructors' Design Learning Philosophies in a Service-Learning Context

## Introduction

Engineering design involves the creation of an artifact which impacts and becomes a part of the world. Although design is generally considered an essential activity of engineering, the nature of engineering design and the cognitive processes involved in this complex activity are not widely understood. How to effectively teach the design process is even less understood. Learning engineering design is a complex process, and it is most often taught in engineering via project-based courses in which instructors guide students through the design process.

In their review of research related to the teaching and learning of engineering design, Dym, Agogino, Eris, Frey, & Leifer[7] assumed that "the purpose of engineering education is to graduate engineers who can design, and that design thinking is complex." (p. 103) They discussed the tension in many engineering curricula between importance of design and engineering sciences. The article also provides a definition of design and states several attributes that good designers should exhibit and that design instruction should seek to develop. Dym et al also discussed a variety of project-based design courses and concluded that, not only do the project-based design courses emulate the team-based environments that most engineering graduates will encounter in industry, "available research suggests that these kinds of courses appear to improve retention, student satisfaction, diversity, and student learning." (p. 114)

Within a project-based design course, the instructor's design learning philosophy can be an important factor influencing the students' design learning experience. A fundamental question is how instructors' view of design learning and design itself impact the student's learning of design and the designs produced by the teams. The research of the instructors' view of design learning and the impact on student learning is limited within the field of engineering education. Friesen & Britton[8] conducted a qualitative study of a specific course trilogy in biosystems engineering that sought to find relationships between the students', instructors', and the industry cooperators' understanding of design, and teaching and learning goals. In the study the participants were asked to articulate their understanding of design and the goals of the courses. Instructors were asked to articulate their approaches to teaching. The results of the study indicated that students were able to articulate a more refined definition of design and the course goals that more closely aligned with instructor goals as they progressed through the course series. Instructors sought to create learning environments which modeled industry. They saw their role as instructors as facilitators of learning in an experiential rich environment.

Much of the research in the design studies field that seeks to develop an understanding of design and design learning does so by studying the design process models used by the designers. Mosborg, Adams, Kim, Atman, Turns, and Cardella[9] studied conceptions of expert designers of the engineering design process by having them "talk aloud" about a given model of the design process, and then to produce their own sketch of the design process model that represented their conception of the design process. The designers were from a variety of fields, and developed

four different general models to represent the design process. In addition, the designers were asked to rate a variety of describing their definition of design. The statements which received the most endorsement from the expert designers focused on the problem definition and communication activities of design. Finally, they were asked to select the six activities that best characterized, and least characterized the design process. The activities that the designers identified as most the important were understanding the problem, considering constraints, and communication. The least important design activities were identified as building, abstracting, and decomposing. Dorst[5] identified two significant paradigms that can be used when considering a designer's design thinking and learning philosophy and methodology: the rational problem solving process that provides a more positivist view of the design process and the reflective practice paradigm, which comes from a more constructivist perspective.

**Research Question**

Because of the benefits of integrating service-learning into the engineering curriculum[6], a growing number of design courses are being situated in the service learning context. Service-learning provides a rich environment for student design learning and for instructors to impact this learning by their design philosophy. The students design products that will be used by real people in a community and are therefore faced with the full range of design challenges including safety, maintainability and service issues after deployment. The kinds of problems the students address are often not traditional engineering problems and stretch students to think and act creatively.

One example of design learning in the service-learning context is the Engineering Projects in Community Service (EPICS) Program where students design solutions to meet local community needs[3]. The EPICS program has a wide range of instructors with varied backgrounds, experience levels, and design learning philosophies. This setting provides an ideal opportunity to explore the impact of the design learning philosophies and methodologies of instructors on the students' learning of design as well as their ability to produce quality designs within the service-learning context.

However, before we can investigate the impact of the instructors' design learning philosophies on student learning and the designs produced, we need to understand the instructors' views of design learning and design itself. We have conducted a pilot, qualitative research study which explores this question.

To gain an understanding of the instructors' views, philosophies, and practices of the learning of design, we explored how they view the impact of their prior design experiences and their experiences in teaching in the EPICS program in developing their views and beliefs about design learning and design. In addition, we explored how they view the design learning philosophies relative to their general teaching philosophies[2]. The relationship between student learning and meeting the community needs can pose some unique opportunities and challenges to design learning which may play a role in how the instructors view design learning, so we also explored the instructors' view of the impact of the service-learning context. This paper will present results from this pilot study conducted to explore instructors' design learning philosophies and methodologies within the EPICS service-learning course structure.

The primary research question for this study is as follows:

- How do instructors in EPICS view design learning and design? (How do they describe their design learning and design philosophies and methodologies?)

Sub-questions that will be explored in this study are as follows:

- How is their design learning philosophy influenced by their design experiences outside of EPICS?
- How is their design learning philosophy influenced by their general teaching and learning philosophies?
- How do the instructors view the impact of their EPICS experiences on their view of design learning and design?
- How do the instructors believe that their design learning philosophy is impacted by the service-learning context?

**Study Design**

Since it is our intent to co-construct an understanding the instructors' views of design and design learning, we will be exploring the case study from a constructivist paradigm. The case study is described by Creswell[4] as "an exploration of a 'bounded system' or a case over time through detailed, in-depth data collection involving multiple sources on information rich in context" (p. 61). This case study is bounded by the experience and views of instructors on design and design learning within the EPICS program. Eventually this case study will include multiple sources of data which would be triangulated to construct a better understanding of the EPICS instructors' views of design learning, and also to provide evidence of credibility and trustworthiness for the study[1]. The multiple sources of data will include interviews of the instructors, observation of the instructors in the project class (lab) settings, and analysis of written feedback given to students by the instructors. This paper reports on the interview portion of the case study.

**Methodology**

We obtained IRB approval prior to the interviews. A solicitation email was sent to a small number of instructors who have participated in the EPICS program for at least two semesters, and who represented different backgrounds. Interviews were semi-structured; we had a list of questions that we intended to ask, but also asked additional questions to further explore or clarify issues as needed. The interviews, which lasted between 60 and 90 minutes each, were audio-taped and transcribed. Each interview was coded independently, then analyzed for common and opposing themes.

The three instructors that were interviewed represent different backgrounds. The first instructor has a Mechanical Engineering background and has worked in industry in various engineering positions for several years. The second instructor interview is a retired faculty member in Electrical and Computer Engineering who has instructed a variety of EPICS teams over the past several years. The third instructor is an Electrical and Computer Engineering faculty member who has been involved in EPICS for nearly ten years.

**Themes on Design and the Design Process**

*Design as an essential activity of engineers*

The first theme on design and design process that emerged was that design as an essential activity of engineers. Consistent with statements in the engineering education literature on design[7,8], design was viewed as an essential activity of engineering by all instructors. One instructor described design as "probably the defining thing between engineers and scientists", noting "engineers do design." Another described design as "that's what engineers do", while the third instructor stated, "It is essential to what engineers do."

*Defining design as a formalized process*

The second theme that emerged was that design was defined as a formalized process. All three instructors described design primarily as a formalized process in which one starts with a problem or concept and goes through the production or creation of a product. For one instructor, the term design was associated with the design process model itself. He stated, "When I hear the term design, I think of the design process." Another instructor described design as "a problem in which there are many correct solutions, so it's open ended in that sense." The instructors also described design by activities and artifacts of the design process model: defining specifications, drawings, prototypes, testing and tests, analysis, and fabrication.

*Design is iterative*

The third theme that emerged was that design is iterative. When asked about words they would use to describe the design process, all three instructors described the design process as "iterative". As stated by one instructor, "Design tends to be iterative, you may think that it doesn't have to be iterative, but I think in real life one finds that the first attempt has some flaws associated with it, and so you want to be willing to redesign." One instructor goes further to describe this iterative nature as a "constant process", noting that:

> "You're almost constantly, either working on a new design, or revising an existing design to make the product more robust, to make it a better value for your customer, to make it more manufacturable for yourself, to reduce the cost, so there is really never a design that I have been associated with that felt it can't be improved somehow."

*View of design process model*

Similar to previous research by Mosborg et al[9] in which the experts' views of design were explored by using the design process model, we presented the following model of the design that we currently use in EPICS to get their feedback on how their view of the design process was the same and different from the model:

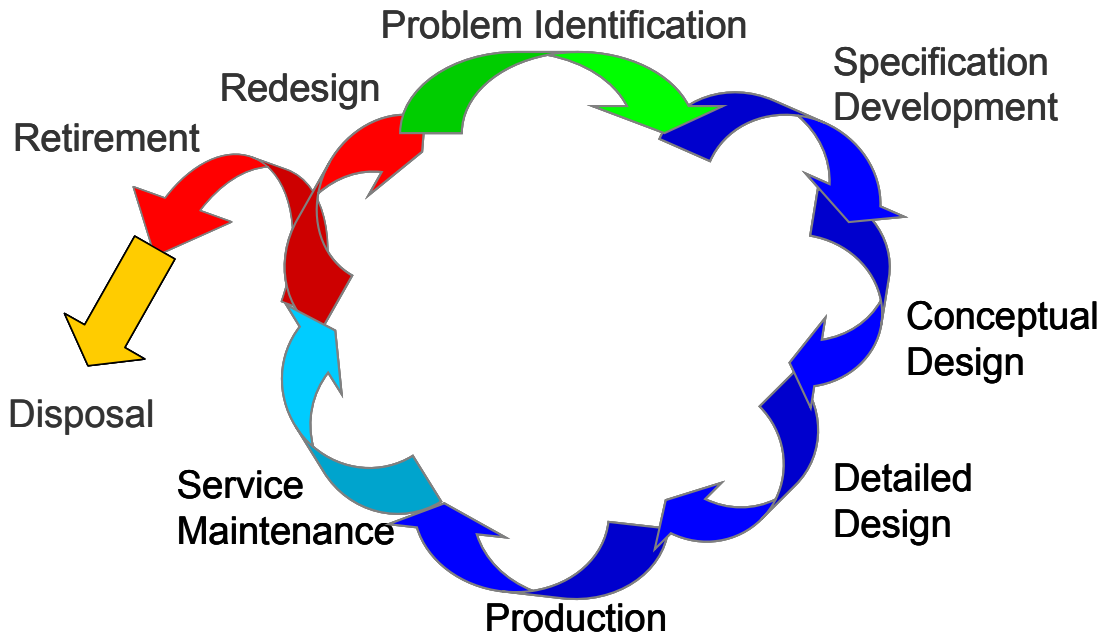


Figure 1: EPICS Design Process Model presented in interviews

The three instructors stated that the EPICS design process model generally agreed with their own model of the design process. They noted differences in the amount of iteration that is represented in the model as opposed to their views of and experiences with the design process. The instructors also noted that the model did not represent that fact that you can be considering several different strategies at the conceptual level, and that one of these would need to be selected prior to proceeding to the detailed design phase. Related to this, the instructor with extensive industrial experience noted that it lacked appropriate gateways between the steps. The design process did not represent the importance of the relationship with the customer:

> "I think engineers don't quite probably grasp as they enter it, is how important the relationship with the customer is. And when we are looking at Gantt charts, and program timing, that have to realize that there are, in most cases, you're working with the customer that has a certain production date, launch date, a date that can't be missed, and so, those things are very important in a design process because it's not only, 'Okay, I have to have a good design that can be produced at a profit, but it also has to be certain time, and it has to meet the customer's specifications.'"

**Themes on Design Learning**

*Learning by doing*

The instructors all stated that they believe that students learn design primarily "by doing". One instructor stated that students learn by:

> "The hands-on, real-world experience that goes beyond the theory. Of course, you have to have a good basics in theory from elementary on in order to be able to do the problem solving necessary for engineering. But beyond that, the experience factor is a big part of how effective you can be in engineering process."

Stated by another instructor:

> "So, I think by doing, it's probably, to me, by doing is probably the best way. I mean, you can do it in theory all of you want, but unless, it, it's got to be actually something, I guess, hands-on, actually doing it. Now, it probably helps if you've got a little bit of exposure to it beforehand, but you're not really going to appreciate it until you get, get in there and actually do it. So, I'd say that's, I don't think they're ways, I'd say that's the way to do it is that you really want to learn design, you've got to get it. And you may learn what you did bad, you know, what you're doing wrong before you learn what you're doing right. But, that's still valuable. So, I guess, by doing."

The third instructor echoes the same message from the perspective of the instructor:

> "You can't teach design, you need to experience design, and so the degree to which you can facilitate students to experience design is the way to go."

*Importance of learning design process model and developing good specifications*

When asked about what students need to learn about design, all instructors indicated that it is important for students to learn the design process model. One instructor stated, "The design process has to be taught in order to really understand design." Related to that, all instructors emphasized the importance of learning how to develop well-defined problem statements and good, measurable specifications in order to be successful. They also emphasized the need for students to especially understand the importance of having a good set of specifications. As stated by one of the instructors, "The engineering field is littered with failures, design failures, because of wrong specifications." The difficulty of learning how to develop these specifications, as well as the importance of developing good specifications, is described by the following observation by one of the instructors:

> "I think it's important that they realize that specifications are important. I don't think there's room in the curriculum, enough time for them to develop a lot of skill in that area. But, knowing how important it is, if they are handed a problem and they don't have a good set of specifications, they should ask for it. They should work with their client to help develop specifications. And I think it would be fair, it would be great, if they could be sensitized to the fact that they should say to their customer, how will you know or how will you judge my end product? And work that into the specifications."

*Importance of learning professional skills*

The instructors also stated that it was important that the students learn project management skills, time management skills, and communication skills in order to be successful as a designer. Noting that design is done primarily by teams in industry, as well as in the university setting, it is important for students to learn to work on a team. As stated by one instructor, students in the EPICS program have an:

> "Opportunity to operate very closely to what they'll most of them will run into when they get into the engineering jobs, and that will have to be working on a team. There are very few jobs, I think, anymore, in my opinion, that you work individually. You are not isolated, you have to interact with the designers or with the technicians, or manufacturing people, the customer, all of those things. So those, those partial social part of that, component to it, there's the technical component to it, there's communication part of it,

all of those things have to come together to become a successful team player, engineer…"

Referring to the professional skills in general, another instructor stated:

"I think EPICS is the kind of program that can, and does, help students realize the importance of those skills, and gives them practice in those things, so I think that is one of the strengths of the EPICS design process."

Further stressing the importance of communication, the third instructor stated, "Communication, I think, is important enough that that has to go throughout the discipline. And I think, the design process has to include communication. So that's important."

In addition, it is important that students think about the ethical and social issues related to their projects. As stated by this instructor:

"The social context has to do with incorporating realistic constraints, because they're going to be societal impact of what you are going, and they have to be aware of that when they're designing things….I think it's an essential part. Because engineers have to be part of the real world."

*Important experiences in learning design*

The instructors also identified a number of "experiences" that they believed would be helpful in developing their skills as designers. Many of these experiences are "real world" issues that design teams in industry experience, such as dealing with the customer, limited resources, balancing and prioritizing tasks, and problems with parts delivery.

"There's never in industry you never have more resources than you need. You always have more jobs than you have resources to complete the jobs, and so that is where you come into, not only time management, but also the evaluation of, triage, method of saying, 'This is what's most important', you know, setting a priorities of the work that you are doing. Some things you're just never going to get to, it's on the list, but you're not going to get to it. And it's because it's not as important, I mean, that is a decision that you make as individual, and then as a manager, you would have to make it to help direct other people, so all through your career, those are real-world decisions they have to make on what do I work on now, where do I commit my resources to, and how that can, how the whole thing impacts the schedule, the design process, all of those things."

All instructors observed the challenges of staying on schedule with regards to the design. Simple tasks take longer than expected, and the plan does not usually allow leeway for unexpected problems or events. One instructor stated that students "probably need to experience failure" in order to understand how difficult design is.

*Varied views of role of instructor in service-learning program*

The instructors saw their role in service-learning program in a variety of ways. Because students lead the classroom (lab) period instead of the instructor, the role of the instructor in the EPICS program is different from most traditional courses. One instructor referred to his role as a mentor, and also like that of upper management:

> "I see … my role in the EPICS team as kind of a mentor. I think if you related it to industry, if this was like a design team, this would be kind of like a role of upper management …, they don't need to know the technical problems, but are going to keep the team on track."

In addition, he sees his role as sharing "real world experiences" that he brings from industry to the team. The second instructor saw his role as "a coach", in which he would ask questions, like "Have you considered this? What is this going to look like 6 weeks from now?" The third instructor described how his view of his role in the program has changed over the years:

> "It's changed. Initially I thought I was … only there for, more or less moral support. I think it's evolved into more like the CEO, and say, be more demanding. Okay, this has got to get done, and … try to make it constructive."

When asked if this instructor believed that students would learn more if the instructor had more control over the classroom (lab) period, he replied, "I think we could get more accomplished, but I think they would get less out of it. I think the struggles are actually that they go through, are part of what they get out of it."

*Importance of design in the curriculum*

Dym et al[7] reported that there was tension in the engineering curriculum regarding the importance of design versus engineering science, which was also expressed to some degree by the instructors. Although all three instructors were in agreement that design is essential part of engineering, they also acknowledged the need to balance design courses in the curriculum with other educational experiences. Incorporating design in the undergraduate curriculum is important, not necessarily to help students become proficient designers, but to expose them to many of the ideas and experiences to help them on their journey to becoming competent designers. The instructors also expressed the fact that design experiences in the undergraduate curriculum provided context for the other courses the students were taking. One instructor stated,

> "I think the more that a student can understand the need for the learning…., the opportunities that they have been given to learn, the different disciplines, the different class work, and relate that to their field of choice…the more meaningful that is." Another instructor stated that the design project "not only brings together just the concepts of the design, but all of the other stuff that they've done. They realize that, 'Well, that's why I had to take all of this math.' Or, 'That's why, circuits were so important even though I'm a computer engineer.'"

The curriculum should increase emphasis on design by helping students connect information and processes they are learning in classes with design, but not necessarily by replacing current courses with design or adding design courses to the curriculum. In addition, the instructors expressed the need for the students to learn the content of the other courses to be competent designers, thus the concern of eliminating content courses from the curriculum.

**Themes on service-learning context**

*Service-learning context provides real world experience*

The relationship between the student learning and meeting the customer needs can pose some unique opportunities and challenges to be able to meet those. One of the positive aspects identified by the instructors was that the service learning context provides a real world experience in which to learn design. It incorporates the whole design process, and there is an authentic customer. Students get practice at defining the problem and developing specifications. As stated by one instructor, "trying to teach design without the service learning context, the instructor is also the client, and so you don't really get the direction of the client's role. So (teaching design in the service learning context) is a much more realistic, in terms of their professional development." Another instructor discussed how this experience has also helped him in better understanding the nature of design:

> "Because, when you see things aren't working, I mean, you get direct feedback about whether things are working or not. So I know I've, my ideas have evolved since I first got started. I mean, in fact, when I first got started, I don't think I had a really as clear of an understanding of what the entire design process was as I do now. And, where students might run into, where the problems they have. So, it's really helped me a lot in terms of understanding what engineering design really is."

*Balancing the student learning with needs of the community partner*

However, the instructors all discussed the trying to balance the student learning and the project work for the community partner as one of the challenges of the service learning context:

> "One of the disadvantages, I think, again it is a trade-off on priorities, but we want to deliver a product, I mean, that is kind of the goal, one of the main goals. We have made this promise, we need to deliver it. Sometimes, the way some of the educational exercises that scheduled to go with it really conflict with that."

Two of the instructors discussed a strategy of working on both long-term and short-term projects simultaneously in an effort to meet both the educational needs of the students, while having projects to deliver regularly to the community partner.

*Service-learning context provides exposure to social issues*

In addition to learning related to design, one instructor also discussed the benefits of learning design in the service learning context is the exposure to the needs of society, and how individual people can make a difference:

> "I think it is very good to see for students…to be exposed to the needs of society, and see that there are not all just taken care of by other people, especially in our case with our community partner. We have hundreds of volunteers. Why do people volunteer? And if you can see that there is a need for it, and see that these are people that society is better because people volunteer."

**Discussion and future work**

The initial three interviews for this project have provided some emerging themes that we will continue to explore as we continue this study. We believe the emphasis of the instructors on the experiences of design, and their consistent view that students learn design by doing, is significant, and we are eager to see if this theme continues when we interview additional

instructors. This emerging theme is already having an impact on how we think about design learning, and has inspired some changes we would like to make to the EPICS curriculum.

However, the interviews did not yield insight on the views of the instructors on what characteristics of the designs themselves they consider important, which we had hoped to gain a better understanding of through this study. We reviewed the questions and our interview techniques to determine how we might be able to get a better understanding of their views. We have interviewed three additional instructors and are currently analyzing the data from those interviews. Until we reach saturation (no new themes or categories are emerging from the data), we will to continue to interview instructors. In addition, we will also be meeting with these instructors again to explore these issues more, as well as to provide an opportunity for member checking.

Some of the responses from the instructors were not surprising given their backgrounds and experiences. It was expected that the instructor with industrial experience emphasized techniques and skills which are used and valued more in industry, and identified more real world problems than the instructors from academia. However, it will be interesting to see if there is a commonality that emerges among instructors with similar backgrounds. There is a great deal of work ahead on this larger case study that, we believe, when completed, will help to better understand how instructors view design and design learning, and eventually the impact on the students' learning of design.

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