

# **AC 2009-1246: VALIDATION OF A DESIGN PEDAGOGY FRAMEWORK USING QUALITATIVE ANALYSIS**

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# Validation of a Design Pedagogy Framework Using Qualitative Analysis

## Abstract

In this paper, we document our qualitative analysis and its results in search for validation of the proposed design pedagogy framework. In the proposed framework, the design learning environment is dynamic with several actors providing and receiving input/feedback. Within the dynamic learning environment, the teachers and students interact through the design task, expectations, the design process, and team composition. All these actors and their activities in this dynamic design learning environment are influenced by predominantly outside parties setting the desired outcomes for design learning, design outcomes, and long term effects (e.g., retention, increased interest in engineering). Through a thematic analysis of interviews with administrators, faculty, students; and classroom observations at Harvey Mudd College, we were able to validate and enhance the conceptual framework by better understanding the relationship between the dynamic learning environment and the desired design outcomes.

## Introduction

The importance put on engineering design teaching and learning increased over the last decade. Despite this fact, however, it is still challenging to discern the most appropriate pedagogic setting that will culminate in long term, deep design learning. Among the reasons for this are: 1) there is no agreement on how design should be taught, or if it can be taught at all, 2) design outcome assessment is challenging (do we assess the artifact designed, if so how do we define good design), and 3) if good design cannot easily be defined, how do we create the best setting to convey the conceptual learning behind it, etc. Consequently, there is a need for a framework of design pedagogy that can capture potential factors with effects on student learning. Such a framework can be of use while comparing design settings for their effectiveness as well as guiding educators in developing course materials, modules, or experiences that can stimulate an effective design learning environment. The study's goals are not only to validate but also to enhance the conceptual framework by better understanding the relationship between the dynamic learning environment and the desired design outcomes.

## Literature Review

Design research tackles with design practice in three different ways: normative, empirical and design-as-an-art. Normative approach theorists have proposed systematic approaches to design<sup>1 2 3 4</sup>. This body of work derives from a rational analysis of design tasks and their requirements, and thus yielded widely-known steps for design (e.g., problem definition, concept generation, etc.). Criticism against the normative approach has emerged from empirical studies in design, depicting design methodology as a rigid prescription that does not work even in ideal laboratory situations<sup>5</sup>. In fact, empirical studies raise the question of whether designers follow any methodology at all. Design-as-an-art theorists<sup>6</sup> postulated that the work of designers cannot be grasped by any methodology, and that the design practice much resembles the work of an artist, who applies different kinds of methods in a flexible manner in a cycle of reflection-action-re-

reflection<sup>7</sup>. All of these have implications for the pedagogy that might be chosen to convey and prepare the setting for design learning.

Despite their contributions to the design research, shortcomings of these approaches exist in explaining, (or taking into account) the relationships between the design practice, design context, and design team performance. For example, the normative approach isolates design tasks from their wider context<sup>8,9</sup>. It neglects most of the specific factors and constraints designers need to cope with, such as economic constraints, time pressure and teamwork<sup>10</sup>. The empirical approach has not been always theory based – a clear direction of research sometimes has been missing<sup>9</sup>. Finally, accepting the design-as-an-art approach closes the door for any effort to improve the performance of design teams, and designing in general with its artifacts. However, to be able to improve design learning, the relationships between design process, design context, and design team performance should be discerned.

Indeed, a number of researchers brought up the importance of studying designers and design tasks in their contexts. For example, Rasmussen et al.<sup>8</sup> suggested that an actual design task cannot be represented by a prescriptive sequential progression from problem formulation to solution. Instead, they suggested a more realistic approach that will be based on separate yet compatible representations of the knowledge domains involved and of decision strategies and heuristics used for navigation in these domains. Bucciarelli<sup>11</sup> and Dorst and Cross<sup>12</sup> emphasized the importance of designer and design team related issues. However, studies of design, which include investigations of the design tasks, the design context, and the design team performance are very rare. One of the main reasons for this has been the lack of a framework that would enable such a comprehensive investigation.

### **Conceptual Framework**

We intend to validate Okuden and Mohamed's<sup>13</sup> conceptualization of design learning, performance. In this framework, the design learning environment is dynamic with several actors providing and receiving input/feedback. For example, the design learning facilitator (professor, etc.) chooses the design tasks/projects, designs the process that teaching will be based on, sets the assessment/expectation standards, and forms the teams. Teams that are given the design task influence team composition by providing feedback to the instructor, the design process they follow, and expectations. All these actors and their activities in this dynamic design learning environment are influenced by predominantly outside parties setting the desired outcomes for design learning (individual and team level learning, and grades), design outcomes (perceptions regarding teaming, communication - design report and artifact performance), and long term effects (retention, increased interest in engineering). Figure 1 depicts these relationships. In the figure, arrows indicate input/feedback sources and directions in the dynamic learning environment.

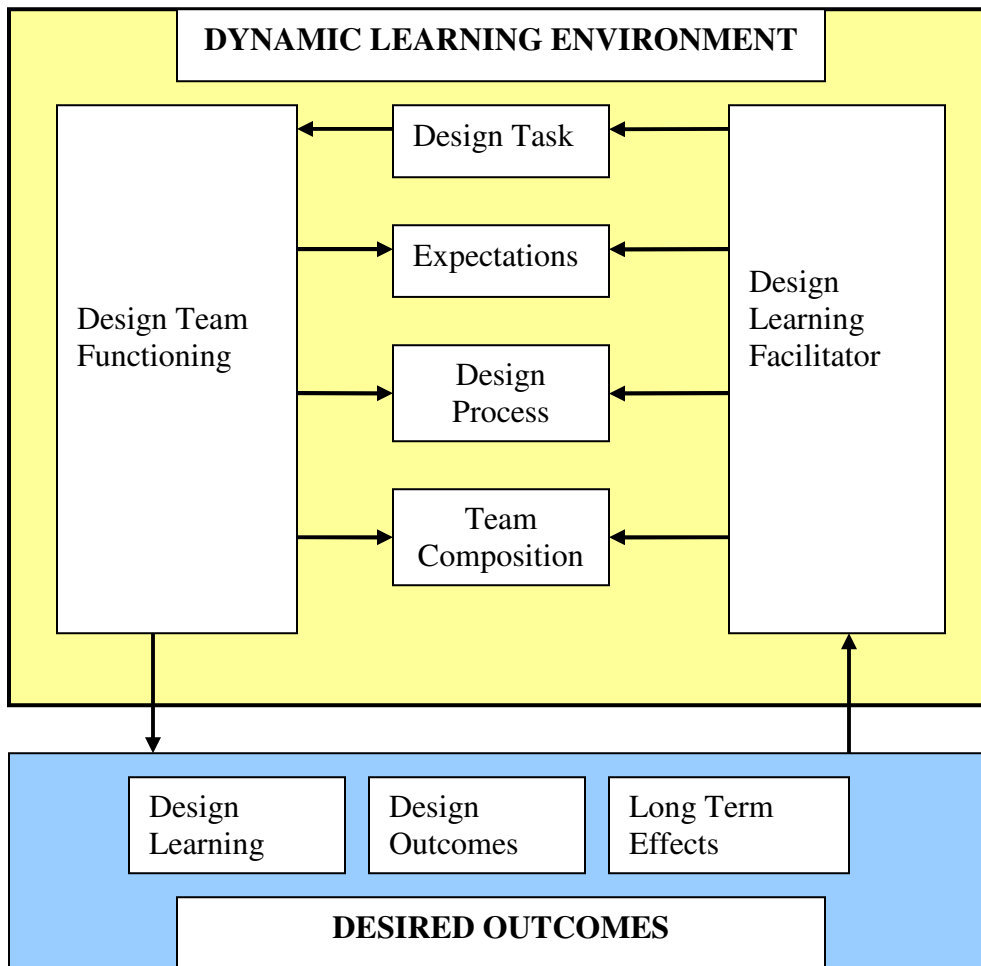


Figure 1: Conceptual Framework for Design Teaching/Learning

## Research Methodology

Data analyzed for this study was collected for a National Science Foundation (NSF) sponsored project that examined six institutions currently producing graduates who resemble the engineer of 2020 as described by the National Academy of Engineering (NAE). Characteristics of the engineer of 2020 include strong analytical and design skills, practical ingenuity, creativity, communication competencies, lifelong learning, agility, flexibility, resilience, high ethical standards, professionalism, business and management skills, and leadership skills<sup>14</sup>. Institutions selected for the NSF study involved analyses of a 40-institution database that was created and developed for the *Engineering Change: A Study of the Impact of EC2000* study (see [15] for more details on that project) and recommendations by the research team's national advisory board. The analyses identified engineering programs and schools that demonstrate superior learning outcomes consistent with the attributes of the engineer of 2020 and comparatively high recruitment and graduation rates for women and/or minority groups.

Data collection involved two site visits at each of the selected institutions by teams comprised of engineering and education faculty and graduate students. During these visits, each team collected data through interviews, focus groups, and classroom observations on the curricular,

pedagogical, cultural, organizational, and policy practices and structures that appear to contribute to the educational distinctiveness of these six sites. For the first site visit, the research team developed and utilized generic protocols for 1) administrators who focus on recruitment and retention of underrepresented faculty and students, 2) faculty who focus on recruitment and retention of underrepresented faculty and students, 3) administrators knowledgeable in student outcomes, 4) faculty knowledgeable in student outcomes, 5) students, 6) underrepresented students, and 7) student leaders.

Analyzing the data from the first site visit, each team then probed on the institution's strengths and education distinctiveness for the second site visit. For example, the research team thought it was prudent to investigate the design course-sequences after exploring the data at one of the selected institutions. Thus, the team then developed protocols that would allow for a better understanding of the design course-sequence. The research team tailored the protocols specifically to individuals identified as potentially rich sources of information from data collected from the first site visit.

Harvey Mudd College (HMC) was not part of the *Engineering Change* database; however, the advisory board for the NSF-sponsored study recommended including the institution because of its national reputation for developing graduates with strong design skills. Because of the school's reputation and from the data collected from the NSF-sponsored study, for this paper, we document our qualitative analysis and its results in search for validation of the proposed design pedagogy framework from the data collected at HMC. We conduct a thematic analysis of interviews with administrators, faculty, and students. The proposed design pedagogy framework (Figure 1) provides the themes used in coding the data.

The research team performed the first site visit during February 25 to 29, 2008 and the second site visit during May 6 to 7 and May 12 to 14, 2008. Members of the team took admissions tours to understand how Harvey Mudd College presents itself to prospective students. They also observed both the first-year design course (E4) and the senior design experience (HMC's well-known "Clinic") during the first visit in February. During the May visit, researchers attended the final presentations for the E4 class and Clinic. Interviews with Clinic sponsors and facilitators (faculty members who "teach" Clinic) provided additional information on the logistics, benefits, and challenges of the Clinic experience. During these two site visits, researchers interviewed or conducted focus groups with 11 administrators, 20 faculty members, 24 students, and 7 industry liaisons. Because HMC's engineering faculty is small in comparison to other institutions, many faculty members agreed to more than one interview so that they could discuss an array of topics of interest to the team. Appendices A to C are protocols designed for the second site visit that specifically focus on the design experience at HMC. All interviews and focus groups were digitally recorded and transcribed verbatim for data analysis.

The conceptual framework for design teaching and learning (Figure 1) provided the themes in coding the interview and focus groups transcripts. These themes include design team functioning, design learning facilitator, design task, expectations, design process, team composition, design learning, design outcomes, and long term effects. The researchers also used an open coding scheme to capture themes or components missing from the conceptual framework.

## Results

### *Clinic Description*

The philosophy behind Clinic is that students can learn more about the engineering profession through practice, similar to how medical students learn to be doctors through clinical experience<sup>16</sup>. At Harvey Mudd College, this real world experience is usually a client sponsored project from industry, which teams of students have an academic year to solve. To be involved with Clinic, companies pay a nominal fee and have at least one employee serve as a liaison to the team. On average, HMC has about 20-24 client sponsored projects per year and usually no two teams are working on the same project.

At Harvey Mudd College, Clinic is the culminating design course, where students apply the design skills and engineering knowledge learned to a client sponsored real world problem. The design course sequence at HMC include a first-year experience (E4), where students first learn about the design process; an engineering tools course (E80), where students learn and gain hands-on experience with simple machine tool applications; and the Clinic. HMC students are required to have at least one semester of Clinic during their junior year. For seniors, Clinic is a year-long project and is considered their capstone project. Clinic teams are comprised of mainly seniors with a junior rotating between semesters, a company liaison, and a faculty advisor.

### *Dynamic Learning Environment*

Elements of the dynamic learning environment (design team functioning, design task, expectations, design process, team composition, and design learning facilitator) were observed or discussed during the classroom observations, student mid-term and final presentations, student focus groups and interviews with faculty members.

### **Design Learning Facilitator**

Each team had a faculty advisor, whose primary role was to mentor and coach the students throughout the clinic experience. They were not the team leader and often times many of the faculty members were on teams where they did not have the technical expertise for the project. The experience was for the students; thus they were responsible for the work. A senior faculty member tells his students:

“This is your work. I am the coach and I want to make sure that they stay on track and in touch with their liaison wants. So we talk about technical stuff and I often will make suggestions and participate in brain storming, but it is not dependant on me. It is their work.”

In contrast, faculty members advising undergraduate research projects would often have a level of disciplinary expertise to help students complete the technical component of their research project. The level of the advisor’s expertise was noticeable to both students who completed an

undergraduate research project and clinic, and faculty. A junior faculty member articulates the difference between “coaching” Clinic projects and advising undergraduate research projects:

“In [undergraduate] research [projects] I treat things differently and if they ask me a question, I will tell them everything I know. With my [clinic] team, if they are asking for basic stuff then I will direct them to a textbook. If it gets to the point where they need to ask someone and they need expert help, I will recommend them to talk to this other professor that knows the material. But you don’t want to be sitting here handing it to them. They need to know what it is like to work.”

As seen in the above comment, faculty members had no qualms in providing technical advice to other clinic teams when approached. As a faculty advisor, they were more likely to guide the students through the design process (i.e., recommending resources) as opposed to providing technical expertise. Faculty members not having the technical expertise helps prevent them from taking ownership of the project. As a senior faculty member says:

“I worry some times that I don’t know... As I said I could not do this [clinic project]. Okay. But on the other hand, and this is some fundamental level truth. This is not about me. I am very happy to be a part of it, but it is these guys work.”

Unlike research projects led by a faculty member, the clinic advisor does not automatically receive intellectual credit for their contributions to the team (e.g., authorship). Since the students designs and develops the solution; the members also decide whether the faculty member deserves credit for his/her intellectual contribution to the project. The following example regarding authorship of a patent shared by a senior faculty member emphasizes the concept of student ownership.

“One of my other teams two year ago now has two patents and when their sponsors ask me whose name should be on the patents, I said you need to ask the teams and let the teams decide and in both cases the teams felt that my involvement was such that they wanted me listed as well. It was not, “The sponsor comes to me and I said okay it is my patent. It is their work.””

### **Design Team Functioning**

Within each team, members select a team leader to organize team meetings, which meet about 1-2 times a week, and to be the main communication person between the team and the faculty advisor and liaison. Leaders are also responsible for leading and delegating work to team members, which may be difficult when utilizing member’s strengths without pigeonholing them. Clinic team leaders needed to be creative in motivating members to complete the task, which can be difficult when they have no interest or the project is not in their preferred area. Clinic leaders learn these through project work throughout the curriculum.

Teams choose the leader at the beginning of each semester, which give the opportunity for a team to have a different leader for each semester. When asked about how team leaders are chosen, HMC students indicated that they are always seniors and then it depends on: 1) who

wants to be a leader, 2) who is willing to be a leader, and 3) who would be good at being a leader. The students indicated that Clinic team leadership is more about organizing the team than about being the person with the best technical skills on the team. However, leaders can not expect to just be managers; they have to pull their own weight on the technical side as well. One of the leader's important functions is to deal with their industry liaison.

This type of team functioning here is more of a hierarchical structure, commonly seen in industry, as opposed to a shared leadership approach, which is more salient in a research focused environment. This is illustrated by comments made by a student who had both undergraduate research and clinic experience:

“My clinic projects were different than my research at first. In terms of like group, I think the leadership skills were very different. Our research was much more of a shared leadership style. So we didn't have a designated group leader.”

The characteristics of a strong team, as described by both faculty members and company liaisons, are similar to a successful team in industry in that teams are able to complete tasks, but also motivated to examine the problem from multiple angles when generating possible solutions. A junior faculty member explains:

“A strong team, first of all, gets the work done. They really look at all sorts of alternatives, look at the problem from very different angles, and they ask questions all the time. They don't just say, “Well this seems to work we will go with this. We don't really understand this, but we will do this any way.” A strong team really will examine, “why is this happening and why are we getting this” and they will go out and talk to [people].”

### **Client/ Liaison**

When sponsoring a Clinic project, companies are not only paying a nominal fee, but more importantly have an employee serve as a liaison between the team and the company. The role of the client/liaison was obviously missing from the conceptual framework. Similar to the design learning facilitator, some liaisons coached students through the design process by providing technical advice and recommendations. In discussing their role, one liaison said:

“I could have from the very start just said this is how to do [complete the design task] and then that would have been done. Instead I let them go through the experimentation process and realize that what they had come up with wasn't perfect and then have to go back and you know rework it.”

Whereas the learning facilitator at HMC mainly served as a coach, the liaison was more importantly the client. Having the company liaison is important, because this allows teams to interact with a real client, where the end product may or may not have real implications for the company. Thus, Clinic is not a simulated project, but instead a real world problem. A senior faculty member says:



“I think one of the most important parts is to have good projects developed by people from outside, the real clients. If it is a capstone design course and I am saying I want you to design a better widget at some level it is like any other course. You know it is just between me and them, but the part of the experience is not just to work together on a team to do a design, but it is partly to deal with a real client. To deal with somebody who wants a result and have to make presentations to them.”

In our conversations with liaisons on their motivation for participating in clinic, they cited two primary purposes: 1) Clinic served as a recruiting tool for their company and 2) Clinic allowed the company to get a fresh technical look at problems they defined. For these companies, they felt their investment in participating HMC’s Clinic was well worth.

### **Design Task**

For Clinic, the design task is the industry problem sponsored by the client. These tasks included a broad range of projects from redesigning the manufacturing process for a surfboard company to designing and building a spaceborne distress beacon for picosatellites (the following website provides a list of past and present Clinic projects:  
<http://www.hmc.edu/academicsclinicresearch/clinicprogram1/projectsday.html>).

### **Expectations**

The client and the design learning facilitator set the expectations of the dynamic learning environment, by helping the students define the design task. In examining and redefining the problem statement, the technical expectations are set for the design team. Since companies are investing time and money into Clinic, they want a product at the end. Thus, the liaisons with input from the design team and the learning facilitator are unlikely to provide a task that is technically impossible, either because of lack of knowledge or resources, for students to complete. For most projects, the expectation is to deliver a product that addresses the companies’ problem statement as one liaison says:

“You get to know the members of the team and it is kind of easy to see over the course of a semester how they are doing, what they bring to the table at meetings, how well they present, how much information they have, and how well they can answer questions. I think it is easy to get an understanding of what their capabilities are and because the project wasn’t that critical and you scope the amount of the project to the students’ capabilities.”

However, when a project is solved easily, the design learning facilitator may set the expectations higher. This is evident in the following comment, where a faculty advisor tells her team that she believes the team can go beyond the needs of the client.

“This was not a non-performing team, but there were happy to get away with what the original project asked for and I said I think you can do more. So I would just tell them I think you can do more than they are asking for here. Why don’t

you come up with some idea that would be interested to the client and propose the idea to them? And they did it.”

Whereas the client may have been satisfied with the original product, the design learning facilitator is not only coaching students to go beyond the client’s expectations, but she is ensuring that the task would still be a learning experience for the design team.

### **Design Process**

The design process is where the design learning facilitator provides the most guidance to the team. Even though within the curriculum students are taught a design process (first E4 and then emphasized throughout their other courses), students still deviated from an organized process. As a coach, the faculty advisor guides the team towards the process they have learned. As one professor says:

“So they get to try [the design process] out early on, and then what we do as advisors in clinic is remind them about the process. Because I think a lot of times when they are given a real world project in clinic, the inclination is just to run out and find an answer, or whatever.”

From our conversations with professors and students, the first step in the process is for the team to understand the client’s demands and write a problem statement. In this step, the faculty advisor is encouraging the team to carefully analyze the client’s problem in order to understand the objectives and constraints of the project. A student talking about the problem statement revision process says:

“They [faculty advisors] also emphasize at the very beginning the problem statement revision... It is like one person giving you the project. Are they sort of laying the ground work? Do they already have an idea of what solution they want? Whether or not this is the right idea, you don’t presupposed a solution when you are writing your problem statement. Instead leave the solving of the problem for later down the line and instead focus on what the problem is.”

This step though is fully interactive with the client, as there are many meetings and brainstorm sessions with the client. A student said:

“I know that for [our] clinic we spent about two to three hours over the course of two meeting with our liaison just like so what do you actually want? What are you planning to do with it? Why do you want it? What is your goal for the whole thing and eventually hassling out because when you got the original problem statement and it was like I want this and we come back and we are like why do you want this? What is this? What is this actually going to do, etc. etc? So we are working our way through and you know part of that is those questions actually enable you to do the project. Because if somebody shows up on your door and said build a satellite. You are like that is great. What does it need or do?”

The interactions with the liaisons are important, because they have requirements that they want fulfilled. One client said:

“I think we had a fairly specific product that would come out of the program at the end which they produce. We had some requirements they needed to meet: size, weight, and power. Then you know we wanted them to do some testing. So we had a set of goals and they got set fairly early on in the project. The things that we wanted to see were met.”

In our discussion with students, they found utilizing the process beneficially in helping them with design. As one student noted about his Clinic experiences:

“It is time to rewrite the problem statement. Like we actually going to use it [design process] and it is like yah. It is going into the final report too. It is like here is the solution that we are representing. How the solutions work and etc. But the very front end of the report is how we got to this solution and why we chose this particular method. So with that sort of justification behind it, it is also kind of nice.”

At Harvey Mudd College, the emphasis then within the design process is for teams to understand and write the problem statement. Faculty advisors are coaching the teams to work closely with their liaison in order to produce a problem statement that will lead to a satisfactory end product.

### **Team Composition**

Students rank their choice of projects and usually placed with either their first or second preference. Teams generally consisted of four to five seniors with a junior rotating between semesters. Students are required to take one semester of Clinic during their junior year in order to familiarize themselves with the Clinic experience. Harvey Mudd College only offers a general engineering program where students can often specialize in different disciplines within engineering. Thus, individual strengths (i.e., communication skills, machine skills) and knowledge in the various engineering disciplines often varied from one team member to another.

### ***Desired Outcomes***

### **Design Learning**

In the conceptual framework design learning involves individual and team learning and corresponding grades. When talking to some faculty advisors who were responsible for grading the team and individual performance, their evaluations influenced by whether the team met the expectations set in the dynamic learning environment. As one faculty member said:

“So it enters into my grade and if I sense the liaison is unhappy in something I can clearly identify with the team or some members of the team, you know I deal with that and clearly my evaluation of the project as a whole is dependent to some extent.”

Grading, however, was not about whether the team produced a great product; but also on the team's performance on the design process. As another faculty member said:

“It is the whole process. So I mean if they tried and they did an amazing job and happen not to produce the final product, then they might still get an A. If they had an easy task and did it and then didn't try than challenge themselves more, then they might not get an A. They might not get a B.”

For Clinic then, faculty did not solely grade teams on the final product but also on their effort and performance during the whole design process.

### **Design Outcomes**

The majority of the clients appeared to be satisfied with the final product produced by the students in Clinic, with about 70% of the clients returning in the following year to sponsor another project. Since the investment to participate (money and time) is non-trivial, having such high percentage of repeat sponsor is a good indication of the products produced by the Clinic teams.

Another indicator of client satisfaction is that the liaisons thought that some students were capable of becoming productive employees upon hiring in a relatively short amount of time, because students were able to develop professional, communication, and teamwork skills during Clinic. In discussing the merits of Clinic, a liaison said:

“I think with the clinic program they not only had to come up with a design technologically, but they had to learn how to interface with us on an individual level. We had video teleconferences and we had I guess a couple of meetings each semester where they would come out and present to us. So they not only had to develop the engineering solutions, but they had to develop those professional skills.

So I think that one interesting thing about the clinic is that they kind of guide them a little bit of that earlier on you know before they graduate. So that hopefully at the end of the process they are more apt to fit right in. I would say at least one or two of our clinic students could come to work for us and be productive you now within a month or two. Whereas some other recent graduates that we have interviewed might take three or four or five months to kind of get up to speed.”

### **Long Term Effects**

The long term effects of Clinic appeared to be the experience gained by the students in working on a real world problem. Both faculty and liaisons mention how constraints such as budgeting, project management can influence the direction of the engineering solution. As one liaison comments about the growth seen in the students:

“They were able to pick up more and more of the experiences that are necessary to give them the tools they need to go into a job and be productive immediately. I think they found out kind of in a difficult way that something can work on paper and in reality they are very different. In that sense I think they have grown and matured somewhat.”

## **Conclusion and Discussion**

All of the components of the conceptual framework were identified through our observations and interviews regarding Harvey Mudd College’s Clinic. A modification though was made by including a client/liaison component to the conceptual framework (**Figure 2**). As discussed in the results section, the role of the client is different from that of the design learning facilitator. In many capstone projects, usually one person serves both the client/liaison and design learning facilitator role. The merits of separating both roles are left for future research.

Harvey Mudd College was one of six institutions in the larger NSF-study. Future research would incorporate the examination of other institutions’ design learning environment (i.e., design-type capstone classes) to further validate the conceptual model. We remind the reader that the implication of this study is not to replicate Harvey Mudd College’s design learning environment. Instead, the implication is to examine whether components of the conceptual framework are incorporated within the engineering students’ design learning environment. For example, finding sponsors who are willing to spend money and time on projects may be difficult; however, when examining the dynamic learning environment do students know what is expected of them?

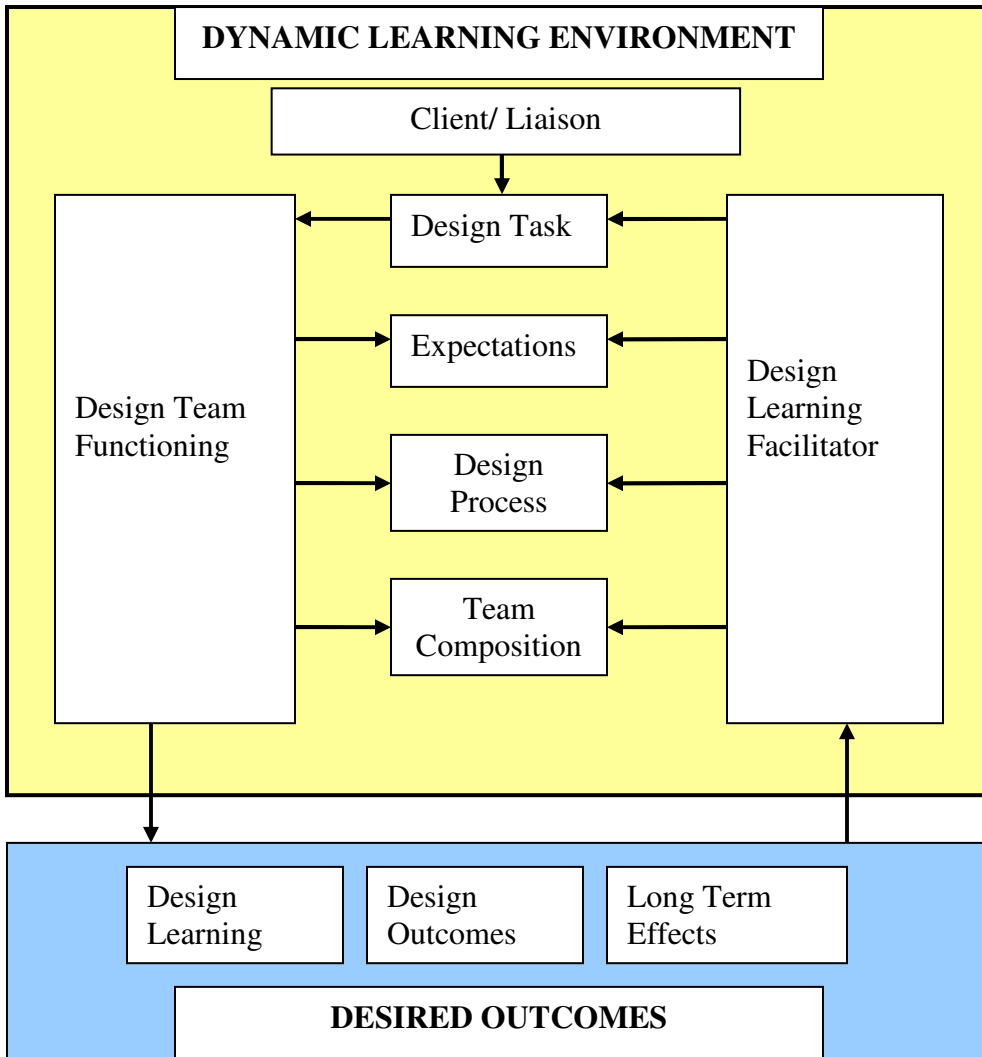


Figure 2: Design Teaching/Learning at Harvey Mudd College

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## Appendix A: Design-Related Questions for Faculty

1. What skill sets do you hope students will learn through the clinic experience? How do you help the students to develop these skills?
2. How do you judge if a design solution is:
  - a. innovative,
  - b. effective,
  - c. scalable,
  - d. cost effective?
3. How often does the faculty advisor **not** approve of the clinic report? What can be the issues related to the report?
4. How are the presentation evaluation forms utilized? Are student evaluations of their peers calculated in formal evaluations of projects? Students' final grade?
5. What type of skills/issues do you address as the "coach" of the team?
6. When does the facilitator intervene for what reasons?
7. How do you react if a project you have advised is evaluated poorly (By Whom)? Has it ever happened? Do you get feedback? What have you learned since you first coached a team? What, if anything, did you do to improve your coaching style? To enhance student learning?
8. How does teaching clinic influence your teaching in other classes?
9. How does the curriculum enable students to transition from E4 to Clinic? (During E4 we concentrate on..., in X we do ...).
10. Does the design experience afford opportunities for students to draw on learning from engineering and non-engineering courses? How?
11. How, if at all, is the systems view integrated into clinic (or design in general)?
12. What are the essential technical issues that get addressed when developing design solutions? Probe for how disciplinary knowledge gets used, and more specifically the role that computation and/or analysis plays in design.



## Appendix B: Design-Related Questions for Students

1. What are the essential technical issues that you try to address when developing design solutions? Probe for how disciplinary knowledge gets used, and more specifically the role that computation and/or analysis plays in design.
2. How did the actual design process progress?
3. Describe some of the difficulties that you encountered while completing the project. How did your team overcome them? What was the role of your liaison in this situation? What was the role of your faculty advisor?
4. Describe your team's thought process in finding a solution. What was the role of your liaison in this situation? What was the role of your faculty advisor?
5. What have you learned from the clinic experience that you will transfer to your future endeavors (job, etc.)?
6. How do you know when your design is:
  - a. innovative,
  - b. effective,
  - c. scalable,
  - d. cost effective?
7. What were your goals entering the clinic? Did you meet them? If so, how? If not, why not?
8. Where else do you get a chance to do design in your engineering curriculum?
9. How do clinic experiences relate to the rest of your experiences in your study of engineering? PROBE: Do you find the clinic is a way to integrate knowledge from other courses?
10. How did you prepare for the clinic experience?
  - a. E4: I learned...
  - b. In .....I learned.....

## **Appendix C: Design-Related Questions for Clients/ Liaison**

1. Why did your company sponsor a clinic project?
2. How important, or “real” the problem/project you have presented to the students?
3. In the course of the Clinic did the original description change? Why did it change? What is your reaction to this?
4. What were your expectations of this investment?
5. What was in it for you individually?
6. Do you feel you have impacted students design learning? How? What areas?
7. Talk about your duties as a liaison to the team. What were your responsibilities?
8. How much time do you devote to helping the HMC team?
9. What are the strengths/weaknesses of these teams?
10. What will your company do with the students’ project?