

Improving Capstone Design Outcomes and Student Development by Coaching the Client*

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Although many capstone programs have made progress in involving outside stakeholders as project sponsors, there is much that can be improved by understanding the growth transitions students undergo and how outside professionals can assist in that growth process. While project characteristics and design course activities are catalysts in this development process, coordinated actions by capstone instructors and clients often activate this development. This article explores tools for assessing and enhancing the skills of professionals who mentor capstone teams. Instructor/client coaching is framed around three naturalistic instructor/client/team interaction windows within the arc of a capstone project. These include pre-project scoping, the preliminary design review, and the detail design review. It is up to capstone instructors to recognize exactly what student development opportunities can be unlocked during these interaction windows and to prepare those involved to take advantage of these opportunities. A client assessment rubric is offered for this purpose as are a set of scenarios about common project situations where capstone instructors could coach their clients.

Keywords: sponsored capstone projects; human development; mentoring; coaching the client; spiral dynamics

1. Introduction

Although companies may provide funding for senior capstone projects, in the end, all sponsored projects are conceived and driven by individuals inside these companies. Understanding individual motivation behind why different clients want a project completed is often a good sign of how they might approach the project, and the degree of mentoring they will need in assuring that they receive the deliverables they want as well as the professional outcome they desire. Managing both of these is critical for seeing repeat sponsorship.

Though most clients/sponsors are strongly supportive of the mission of an external client/capstone experience for students, some are not sure of their role in developing students' professional skills within these projects [1]. The intent of this paper is to provide guidance to capstone instructors, based on the experience of two veteran capstone clinic directors, so capstone projects are successfully completed and professional development is at the highest possible level for everyone in the capstone ecosystem—students, clients, and professors.

While there is much written about the design and product development process, these treatments assume involvement of a well-prepared and professionally mature design team guided by a trained project manager and client/customer [2, 3]. Professional attributes sought in team members associated

with different capstone course models are mapped by Davis et al. [4]. When attention has been given to developmental issues, this has focused exclusively on students and is commonly done via reflective writing assignments [5–7]. In contrast, the role and responsibility of capstone instructors along with capstone project clients is relatively unexplored. This article seeks to fill this gap by investigating the following research questions:

- (1) What realistic student development goals should be articulated and upheld in academic capstone design projects?
- (2) What explicit actions on the part of capstone instructors and capstone clients, working together, are required to facilitate this development among engineering students?

To answer these questions, a social development model is required that can explain client, student, and instructor evolution in the context of a series of developmental activities. Also required is a recognition that different individuals inside the capstone ecosystem are at different developmental places when they start their engagement. All parties will grow, but the developmental endpoint will not be the same.

The data to support the conclusions in this paper come from statistics derived from 50 randomly selected projects that are archived by the first author's project management software. Students in this class are required to keep all correspondence with the client archived on this system, called Base-

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camp. The quality of these archives varies, from students and clients who are very diligent in maintaining high fidelity communications, to clients who refuse to use the Basecamp system. Projects reviewed range from 2007–2014. Ratings were done using a client performance rubric that examines client behaviors related to four different dimensions—personal motivation, professional experience, interaction ability, and institutional design process. Results are interpreted based on the authors' shared experience from running more than 350 capstone projects over the last twenty years [8, 9]. To complement this analysis, a set of archetypical client scenarios are formulated. These examine best practices in coaching the client at natural intervention points within a capstone project.

2. Spiral dynamics social developmental model

In prior work, the theory of Spiral Dynamics was reviewed and explained in the context of engineering education [10, 11]. Fundamental to Spiral Dynamics is the notion that humans and societies pass through developmental levels as they mature and grow, and these different levels inspire different challenges as that change occurs. This change is tied to empathy development, and makes the case that as individuals continue to evolve, they become more data-driven in their relationships. This leads to an evolved balance in individual judgment between responding to external cultural cues and evaluating data more objectively.

There are 8 levels in the Spiral Dynamics model. The levels alternate between '*I modes*' which are more individual focused and '*We modes*' that are more community focused. The levels are designated by different labels as shown in Fig. 1. Each level has characteristic values and mindsets, referred to as value-Memes (Survival, Magical, etc.), or v-Memes, within the Spiral Dynamics model. V-Memes occur in paired sets, with the first '*I*' mode driving personal development, which is then consolidated in the following '*We*' mode that generalizes the development occurring.

1. **Survival/Automatic/Instinctive** (*I mode*)—characterized by individual survival needs (water, food, shelter).
2. **Magical/Tribalistic/Animistic** (*We mode*)—characterized by group-shared rituals and belief structures, but no strong leadership structure.
3. **Authoritarian/Egocentric/Exploitative** (*I mode*)—characterized by groups of people occupying stratified positions of power and

privilege within the group, as well as limited independent decision-making authority except for those at the top of the organizational structure.

4. **Legalistic/Absolutistic** (*We mode*)—characterized by groups of people who occupy stratified positions of power and privilege, but who are subject to a body of law that applies to all, restraining individual power and decision-making capability.
5. **Performance-oriented/Goal-Based** (*I mode*)—characterized by communities who value independently selected and formed relationships, and who assume a group structure that supports achievement of a shared goal or some sort of culturally desirable performance.
6. **Communitarian/Relativistic/Sociocentric** (*We mode*)—characterized by people-oriented societies that highly value each individual and are based around egalitarian principles and codes of conduct that protect individuals' rights.
7. **Global Systemic/Integrative** (*I mode*)—characterized by individuals who recognize the relational dynamics present in all lower levels and opportunistically combine these to achieve higher goals and purposes. This v-Meme was the first in what is called 2nd Tier v-Memes, which have a step function of higher awareness of self and world.
8. **Globalist/Renewalist** (*We mode*)—characterized by a very small number of individuals worldwide who strive to create large systems that bring together different cultural sub-systems to achieve goals on a global level.

Figure 1 shows the emergent structure of Spiral Dynamics—in particular, the notion that once a certain level is evolved to, that person or social system has access to that level, as well as all levels below it. Navigating the different v-Meme levels requires that central beliefs about the world be challenged and reconciled. Those who are open to embracing the next higher level are said 'evolve' and engage in experimentation with the next level. Those who actively reject the next higher level are said to 'devolve' and often compel similar behavior in others.

In capstone design, most students in the cohort age of 21–26 are naturally going through a transition in relational development, becoming less externally defined and status oriented (Authoritarian/Legalistic v-Memes) and more focused on self-improvement in support of a shared vision (Performance/Communitarian v-Memes that correspond to performance-based communities of practice). This evolution of personality, vital for the results-

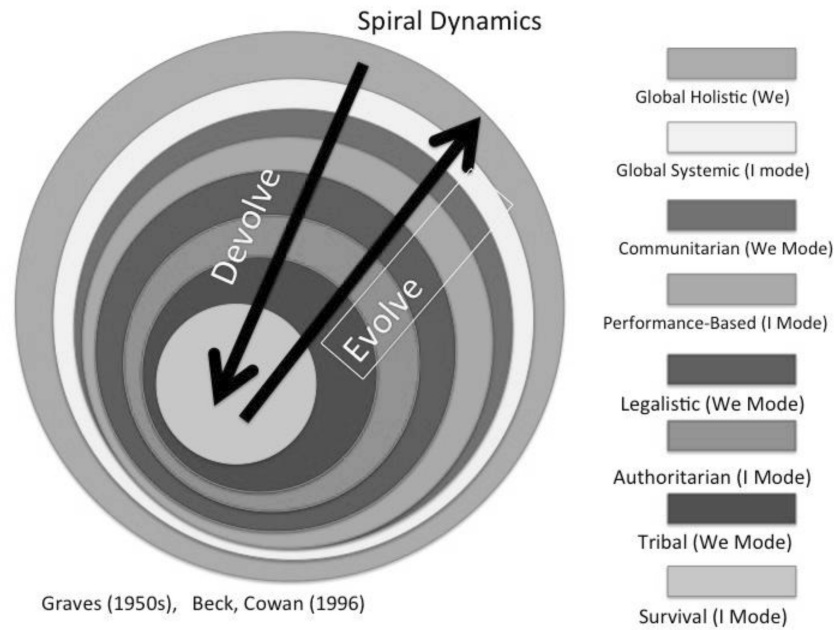


Fig. 1. Graphical representation of Spiral Dynamics.

oriented engineering profession, maps directly onto the capstone environment, and with assistance from clients, can be accelerated.

3. Performance-based course design

Different capstone classes will necessarily require different client mentoring styles and abilities. For a capstone class that centers itself primarily on analysis techniques, the client is also a technical advisor, reviewing and directing student work. But for many capstone courses, such as the authors', the main goal is giving students an authentic experience in executing, managing and completing an engineering design task for a customer [12, 13]. In this context, a central element is successful project completion of an agreed-upon goal with an industrial client. Students must meet the project specification in order to complete successfully the project. There are several reasons why this is a good goal for a capstone class.

- It drives coherence between students' capstone learning experience with the outside world.
- It drives student maturation because the students must suppress their own egocentricity and ascertain what the customer actually needs.
- It supports the well-established, canonical design process of specification->preliminary design review->final design review-> product manufacture.
- It provides an outside review of students' technical communication proficiency, because students must produce reports for an outside audience.

- It emphasizes the role of a third-party in the educative process, that of a customer.
- It fulfills ABET's requirements for a design problem with realistic constraints.

The mission for a product realization capstone program is that students should work jointly in teams, where performance is determined by meeting a goal of completing a project to specification, in a supportive community of faculty members, fellow students and sponsoring companies and their representatives. In the verbiage of Spiral Dynamics, this involves students functioning in a Performance-based Community while completing their projects. This is in contrast to the typical academic environment which is far more Authoritarian/Legalistic. As a consequence, capstone students often find themselves placed into a new relational space with which they have little familiarity. Students must complete a real project to the satisfaction of a third-party, combining efforts with other students. Peer-level and customer information sharing isn't optional—it is vital. Authority no longer rests solely with the capstone director as these individuals have multiple groups to oversee who are pursuing widely different projects. Students must seek out other individuals, resources, and data sources outside the familiar academic hierarchy.

4. Client motivation

Based on the authors' experience, capstone clients participate in student projects for one or more of the following reasons:

1. **Work Product.** They want the work completed, and likely realize that the value of the student work will be relatively cheap compared to other alternatives.
2. **Recruiting.** They are hiring, and human resource needs can be meeting students through project sponsorship.
3. **Instructor Connection.** Often, sponsors are former students of the capstone director, and want to continue a positive relationship with the supervising professor.
4. **Institutional Connection.** Very often, sponsors are alumni of the university where sponsorship occurs. These loyalties can be very strong on their own. And also since project sponsorship often demands visitation of the campus from the project sponsor, the individual can combine a need for reconnection with the larger institution with corporate demands in a synergistic fashion.
5. **Student Development.** Late career individuals often enjoy the student mentoring process itself, and so are primarily interested in the student/mentor interaction.
3. **Instructor Connection.** Clients with a strong instructor connection are often great capstone sponsors, in that their Communitarian v-Meme is emergent in their desire to maintain a friendship-oriented relationship with the capstone instructor. This is often coupled with strong Legalistic/Absolutistic v-Meme identity with the institution.
4. **Institutional Connection.** Clients with strong institutional connections have strong 'We' v-Memes, often absolutistically identifying with their home institution, as well as appreciating communitarian v-Meme experiences outside the capstone clinic with other alums (such as sporting events). The idea of maintaining institutional reputation also drives Performance v-Meme behavior, and makes them accessible to coaching.
5. **Student Development.** Clients primarily interested in student development are typically characterized by a combination of Communitarian v-Meme behavior, as well as emergent Global Systemic self-awareness. Clients with these characteristics can make great sponsors, but often need reminding that students need Performance v-Meme development for successful project completion. It's not enough to follow a design process. Results must follow.

Of course, no individual is monolithic and most capstone clients possess multiple motivations. Successful detection of client motivations by the capstone director, however, is important to make sure each client walks away from the experience with what they were seeking. Regardless of where the client is developmentally, the capstone instructor must help guide growth of both the students and the client to assure that both engage in a meaningful learning experience that yields the desired engineering products. Those who espouse each of the five motivations can be characterized in a Spiral Dynamics context.

1. **Work Product.** Individuals desiring a work product from students are often a combination of Authoritarian/egocentric and Performance-Based v-Memes. Their primary goal is reaping value from the capstone process for their company. This is not necessarily a negative attitude, as long as such clients are monitored for the reasonableness of their demands.
2. **Recruiting.** Clients with recruiting mindset are often Authoritarian/egocentric, primarily interested in benefit to their company, and view any monies charged as surrogate for paying a recruiting firm. The authors' experience suggest that this is less desirable than a work product focus, in that these clients often do not have a well-developed Performance v-Meme, do not care if the students complete value-added work, and can be poor communicators during the class sequence.

Not surprisingly, the goal of an individually tailored coaching strategy is balancing the relational v-Memes that clients already possess, and developing the higher v-Memes the students do not possess. For clients with a more communal perspective, emphasis must be put on 'I mode' V-memes—the performance and egocentric status of the client (clients must convey to the students that they must complete the project, or the client will lose face in their company.) For clients with a more individualistic perspective, coaching will involve developing stronger 'We mode' identification (we're all in this together, and every individual has a role in completion, or 'you're all going to be alums of your institution, and your performance reflects on your institutional education.')

Completing the project work and essentially guaranteeing completion from the outset is part of a successful capstone design recipe. It keeps everyone at the table regardless of the level of charity and high-mindedness they might possess. The other main point to remember is that for both clients and students, and to a lesser extent, the supervising professor, the whole effort is a transformational process. Hence, along with social analysis, it is important to introduce a time-dependent framework for the design process.

5. Developmental pathway

The Arc of the Project (Table 1) is a temporal construct developed by the authors as a way of communicating what has become a standard heuristic for industry-sponsored design projects. The steps of the design process, laid out in this progression, are well accepted in the larger design community [2, 3].

Client expectations in the Arc of the Project are intended to accelerate design team performance development and are structured according to the principles of Spiral Dynamics. Students in the academic environment are used to authority-based teacher/student relationships that are non-empathetic in nature. Upon being given a project with industry, students, without any other model, will most likely substitute the client into the authority role of the professor. This is problematic, as it will then create passive behavior. Either students will (a) wait for information from a qualified authority who has been defined as an expert, or they will (b) arbitrarily select information they believe to be true (egocentric self-authority). In the first case, if the information is passed from the authority to the student, there is a high probability of information corruption—especially if there are multiple links in the information transfer chain (professor → student → student.) In the second case, students are prone to arbitrarily jump to conclusions based on their own, past egocentric experiences as a matter of expediency in solving the problem. They are unlikely to consider others' viewpoints, or synthesize a larger view of the design space.

A scenario where the student must consider a script where customer satisfaction is paramount,

changes the project dynamic considerably. Ideally, what would happen is the following:

- Students are given a project they desire to work on alongside team members they have had some authority in choosing.
- Students are given a script on how to interact with the client so that they can write a specification.
- A priori, without the students' knowledge, the client is coached on the script—namely on students' likely perception of the client and forced adoption of the role of mentor.
- Students visit the client, and client informs the student he/she is not a mentor, and discusses their role as a customer with the students.
- Students are then forced to empathetically evaluate the client and their emotional state—are they happy with the visit, specification, and other project aspects?
- Students then return to their home institution and are forced to forge independently generated, performance-based relationships with each other.

If the client has been coached, they know they must be explicit in communicating their emotional state. They are supposed to tell the students when they are happy, as well as when they are unhappy, and appropriately drive inquiry with the students if they are not satisfied. It is important in the coaching process to let the client understand that unlike many academic situations, they are not to withhold project-specific information from the students. At the same time, if a specification document does not address the client's needs, then the client should continue a dialogue with the students until agreement is reached.

This pattern is centered on developing a set of appropriate goals that describe the performance

Table 1. Arc of the Project

	Scoping	Specification	Preliminary Design Review	Final Design Review	Product Delivery
Timeframe within project	Pre-team assignment	10%	35%	70%	100%
Student Role	Express project preferences and qualifications in response to an approved list of projects	Students meet client for first time and create list of specs for measuring pro-jet success	Viable design concepts are discovered, validated, and selected for synthesis in a system design	Detailed design documents are created for the final prototype; expenditures are approved; problems in implementation are identified and addressed	Prototype is tested against specs; final presentation is made to client's organization; hardware and final report are delivered
Client Role	Project scope and budget along with course roles are reviewed and agreed upon with capstone instructor	Client hosts the design team at their facility and acts like a customer	Other company engineers and stakeholders are involved; feed-back is given with tough love	Client freely shares design knowledge and know-how; collaborates in resolving technical issues	Participate in assessment of project as well as professional development outcomes

and goals of a system and this interaction falls into the Performance v-Meme. Clients may ask for things that are outside the realm of possibility for the students to complete. Students must be prepared then to respond with information that conveys their situation and limitations to the project sponsor. These types of interactions and associated documentation produce alignment in project goals between the client and students, insuring that the project gets off to a good start.

6. Client assessment tool

The challenge in coaching the client then becomes assessing the client's ability to accelerate the students along the Arc of the Project toward final completion. Four factors that characterize client performance are hypothesized—project motivation, professional experience, interaction ability,

and institutional design process of the client's organization.

Students in the first author's capstone class are required to keep all correspondence with the client archived on the Basecamp system. The quality of these archives varies, from students and clients who are very diligent in maintaining high fidelity communications, to clients who refuse to use the Basecamp system entirely. Projects reviewed range in date from 2007–2014. 50 randomly selected projects were surveyed from the Basecamp system. Scores were assigned using a Likert scale from '1 = not conducive to project success' to '5 = highly conducive to project success.' The scoring rubric is shown in Table 2.

Clients were rated in the four areas prescribed by the rubric. From the 50 projects mined from Basecamp, the statistics shown in Table 3 were obtained. It is important to understand that the first author

Table 2. Client Assessment Rubric

Level of Performance	Project Motivation	Professional Experience	Interaction Ability	Institutional Design Process
Low - 1	Not motivated—assigned project from supervisor, no input into scope or process	No engineering experience and no experience with the design/development process. Unfamiliar with physical laws that govern design.	Egocentric, focused on satisfying immediate needs. Not attuned to project/course timelines.	None. No knowledge of design process—only wants the output/result. "Throws problem over the wall."
2	Some motivation—not involved with the decision to do a project, but contributed to scope	No engineering experience, but some experience with design/development process. Some awareness of physical laws.	Mediocre verbal/written communicator, often difficult for students to contact, some appreciation for project and course timelines.	Aware that design process exists, but is uncomfortable with concept exploration. Espouses pre-conceived solutions.
3	Modest motivation—had some flexibility in acceptance/refusal to do project, has some interest in mentoring students	Starting engineer, received coaching on design and development from a mentor inside the company. Aware of diverse physical laws. Has limited experience creating solutions.	Regularly accessible to students, can provide example documentation, can correct student requests for appropriate professionalism.	Informal design process, backed by some history of creating design solutions inside the company.
4	Highly motivated—contributed money/resources to the project, participated in scope, will benefit from a successful completion, has some relationship with instructor	Engineer with 5+ years of experience, uses multiple development processes, has well-founded idea of potential solutions that have solid basis in the laws of physics.	All of the above, plus an empathetic, affirmative communication pattern that emphasizes shared understanding. Helps the instructor stage the project for success.	Multiple solution, multiple stake-holder design is part of company's ethos, and has identifiable project phase gates. Sees synergies with capstone course requirements.
High—5	Very highly motivated—all of the above, along with institutional connection with the university. Likely an alum, or former student who is familiar with the process.	All of the above, plus experience with empathetic mentoring of younger engineers, understanding the typical mistakes young engineers make, as well as an appreciation for the diverse thinking offered by young engineers	All of the above, plus the ability to provide timely feedback to the instructor if things are not going according to plan.	Multiple solution design culture, with established, documented process and larger awareness of modern design methodologies. Enriches the standard design techniques that are emphasized in the capstone course.

Table 3. Client Statistics

	Project Motivation	Professional Experience	Interaction Abilities	Institutional Design Process
Average	4.0	3.9	3.6	3.4
Standard Deviation	1.0	1.1	0.9	0.8

maintains active relationships with a large percentage of project sponsors, and virtually all of the sponsors of projects evaluated for this study. In order to stimulate recall of the particular project, messages were read—especially client responses. Additionally, final reports, which contain final drawings as well as prototype pictures were reviewed for determining project success. Finally, sponsors are required to submit a project approval e-mail. These were also read and used in score assignment.

A review of individuals at the tails of the distribution reveals some interesting patterns. For those projects at the high-end, all clients were successful engineers themselves, and believed in a structured design process. While some coaching was required regarding the need to act as a customer, a clear conceptualization of a multiple ideation design process did not need to be explained to them. Once they understood their social role in the process, the rest came naturally.

Not surprisingly, for those projects on the low-end of the distribution, all the clients save one, were not practicing engineers. Difficulties calibrating themselves to physical principles, the ideas of basic statistics, and unrealistic expectations from flawed understanding of basic physical laws stymied their ability to accept that there even was a design process. This lack of conceptualization made it difficult for students, who were in the learning process themselves, to backfill the client's ignorance about the technical problems that were uncovered and why these were significant. Clients without some grounding in the design process behaved like students without instruction—they would leap to conclusions, and not use standard deconstruction techniques to prevent end-of-design failure, and would often encourage these bad habits in students.

There were three additional observations from examining the project pool. First is that a large majority of clients that have come to the capstone clinic have been real assets to the students (~80%). Even those interested in the cheap labor aspect of the program, harbor good intentions toward project completion, and having the students feel positive about work well done. Secondly, for a very small group of problem clients, remediation seemed insurmountable. For example, clients without fundamental knowledge of the laws of physics, were

especially difficult to please, and often gave arbitrary input as well as direction to the students. Finally, a good goal in coaching capstone clients is bringing up the performance of the average client to that of the great client. Part of this is recognizing that clients are undergoing their own evolution within the Spiral Dynamics scheme, and are not likely to jump multiple v-Meme levels within one project cycle in a capstone design clinic.

7. Client interaction and intervention plan

There are three time-periods during the Arc of the Project where coaching the client will have maximum payoff. These are described below along with common risk factors and remediation plans.

Pre-Project Scoping. Ideally, for every project—especially the initial project between the company and the program—the instructor and the client will have met face-to-face themselves and established effective communication and a meaningful relationship before project initiation. The instructor then has the opportunity to tour the facility or factory where the client works, understand the project and deliverables themselves, and convey to the client the various observed abilities of the student cohort, including perceived strengths and weaknesses. The client can also explain the project in detail, and a shared vision for scope can be generated.

Understanding and assessing a potential client's v-Meme structure can also provide valuable insight on how the supervising professor must advise the client. Clients need to understand that they are assisting students with the transition from a more passive, Authoritarian v-Meme relationship with an established authority, to a more productive, goal-based state of mind that involves interaction with a client. Authoritarian clients slip too comfortably into the vacuum left by the supervising professor.

There are also risks associated with higher-level v-Memes. Legalistic clients, insisting on 'fairness' can end up stepping into a supervisory role because they believe that they are responsible for balancing work load within the capstone team. Communitarians can let goals slip in the interest of preserving group harmony. Global Systemic thinkers, with their self-awareness, understanding the role of process in design completion, and receptivity to coaching from the supervisory professor, need appropriate calibration to understand where the

students are, technically, cognitively, and socially. Performance/goal-based clients are frequently the best clients because they engineering performance goals that are matched to student development needs. However, these individuals need grounding in the strategy and methods of the design clinic.

Some risk factors associated with project scoping are:

- **Low science and engineering aptitude.** Individuals approaching a capstone clinic with devices that primarily violate the Second Law of Thermodynamics will often make their way to the doors of the university. Often, start-up entrepreneurs, convinced they have found a way to ‘beat the system’ will want supplemental research done by undergraduates because of the pricing
- **Low budget, highly prescribed project.** Insufficient resources and fixed timelines can forecast client inability to take input on project scope. Individuals that have a certain quantum of engineering they must get done, regardless of capabilities of the students, tend to be, after initial enthusiasm, dissatisfied with student progress regardless of actual performance.
- **Under-investment in the scoping dialogue.** Individuals not at the scoping meeting and with no alumni link to the university should be watched carefully. There are many pride issues associated with undertaking and successfully completing projects within an office environment, and these should not be underestimated as positive drivers.
- **Lack of a formal design process embraced by the sponsor.** While smaller firms cannot be expected to have a formal, gated design process, larger operations should have some evidence of a design culture. This usually becomes an issue when the primary focus of the company is centered on something other than the primary thrust of the majors in the design program—such as soliciting a primarily electrical engineering project from a company that specializes in mechanical engineering product lines.

With risky projects, the instructor should not dismiss the option of walking away from the project in question. That said, there are strategies the first author uses where much of the risk can be removed.

- Have a well-designed presentation, given to the client, and preferably on site that have clear intermediate and final goals of the project. Express the desire of the program to create independent students with the incumbent minimal time mitigation, but don’t hesitate to lay out a timeline with clear commitments that the client must make in order to have a successful project.
- Invite (or make mandatory) the client to visit the

campus and see your operation. Usually, a non-committal client will not make the effort.

- In the scoping visit/interview, construct a timeline with the client that is more specific than the Arc of the Project. With the client, estimate the number of hours for each designated task. If this totals to something greater than the students can reasonably do, then decline the project or seek modification.
- Construct fallback scenarios for the final deliverable during the scoping visit. If the client demonstrates flexibility in this, they likely will be a good client.

One of the keys to the first author’s success is the 120% Rule—the client should ask for a deliverable that is approximately 120% of what the client will be satisfied with. This extra 20% will often be delivered by the students, but also builds in a buffer for unexpected delays. Seniors need to have confidence that projects can be completed on time, and unexpected delays that can come from part ordering and such must be planned for and understood by the client a priori. All three players in the ecosystem—client, students, and instructor—must be on board for successful completion. Poorly scoped projects, from the back shelf of non-completable projects, are not suitable. Good scoping sets up the students for a successful specification trip. And by having the students write the specification, they clearly know what is expected of them.

Why not just intervene during the period that the students are writing specs? In order for client intervention to be effective and performance-based, student-client interaction must necessarily be limited at the start of the project. Initial client reticence forces the team itself to develop independent, trust-based data driven relationships intra-team (Performance-based thinking), without the distraction of familiar authority from a professor, or the students’ assumed role of the client. This follows from the experience of the authors, as well as the well-known ‘forming, storming, norming, performing’ process documented by Tuckman [14].

Preliminary Design Review. The second major step—the preliminary design review (PDR)—takes place approximately 4–6 weeks after the initial specification visit. The idea of placing the PDR in this time window is that it gives the students time to form a cohesive work group amongst themselves [14]. Once the group has reached consensus with a variety of modalities for solving the problem, the well-coached client will bring together a large group of stakeholders on his/her end. Hopefully, some of these will also be practicing engineers that can act as silent advocates for the students. They can facilitate the duplex dialogue needed to bring the multiple

concepts down to one that both client and students agree can be engineered for the final design. Ideally, the PDR creates coherence between students and clients midway through the design process. Major scope change after a completion of the design concepts should be discouraged unless there is a major issue of relevancy to the client's needs. Making sure the client understands this before entering into the final design is important, and the client should be coached to expand the range of preliminary designs to account for newly discovered factors.

A well-coached client will also realize some important factors about how the Arc of the Project must continue. Small amounts of scope creep are acceptable. Major scope change is not. The client, being aware of the students' natural tendencies toward viewing the client as the authority figure, can draw the students into a negotiation of various parts of the specification to insure the project is completed on time for students' graduation or class completion. Additionally, a sophisticated client can help students understand the process of design concept merging, as well as timeline-to-completion construction. Reinforcing the fundamental nature of the team by not showing favoritism to any particular member of the student team also can help students understand that they're in it together. Since the client has been coached to not interfere with individual students in the group (such as tracking work progress of individuals) the group will be much more likely to remain active and not wait for instructions from the sponsor.

The best clients will have formalized processes for Preliminary Design Reviews (PDRs), as well as multiple points of contact before any formal PDR. In that case, it is best to let the in-house process roll forward without interference. For those clients that do not have such formalized processes,

- Make sure the client makes the students aware of any preferred vendors or part suppliers that are regularly used by the client's companies. Students have a tendency to always go for the lowest price, which is often not the best solution.
- Encourage the client communicate with students before the PDR about trade-offs and balancing in the specifications. Clients, by making explicit their desires, can compensate for preconceived and arbitrary student biases that are often the result of inexperience.
- Request that clients provide a documentation standard. PDR formats that originate from the client's company are useful in helping students visualize what is necessary of completeness in professional communication.
- Encourage the client to invite as many stake-

holders to the PDR as possible. This can insure against project surprises and resulting scope creep in the future.

By the time of a successful PDR, teams should have successfully established independent, performance-based relationships with each other. Sponsors ideally will assume a combination of goal-based behavior and appropriate authority in providing additional information to maximize project success. Empathetic, duplex information exchange should be the rule of the day, so that when students lack familiarity or understanding with the technical aspect of a project, they are unafraid to approach the client to resolve confusion.

Final Design Review. At this point, both client and students have evolved in their respective roles, in an empathetic performance-based community dedicated to project completion, with appropriate individual roles assumed by everyone on the project team, as well as the sponsor. By having the client treat the students with a group identity, now the client can force-feed students the technical information that likely only the client knows, without disrupting the general momentum of the student team. The authors have observed this phenomenon multiple times, and this type of dynamic creates the highest value-added projects to the customer's organization.

It is important at this point to communicate to the client that any information withholding will likely only negatively impact project outcomes. Any explicit pedagogical efforts on the part of the client should be disallowed—the best learning experience the students can have is implicitly coded in the project success. When both students and clients finish the PDR with a high level of coherence on what the final design will be, there is often little that can sabotage project success. Nevertheless, there are still project risks that can be attenuated with good client interaction. These include,

- **Parts ordering and acquisition.** Clients can leverage their relationships with parts suppliers to expedite material acquisition for the final build. This should be part of the final design review dialogue.
- **Professional standards of work.** Students often are not well-versed in drawing protocols, dimensioning, and tolerancing. If possible, have the clients provide and explain examples of final drawings that are commonly used within their organization.
- **Managing project completion.** Often, students are unable to calibrate efforts appropriately for detail at the end of a project. If the client is an inexperienced engineer, it is appropriate to expand the leadership team to include local technical staff

that can assist in preparation of design documentation and use of manufacturing equipment. If the client is an experienced engineer, it is appropriate for the instructor to encourage the client to shift into a mentorship role and help students maximize productivity in the final weeks of a term.

Methods for mentoring clients for optimal student development in the final stage of the project include:

- Encourage the client to maximize their availability in the final stretch of the project. Encourage specific, detailed questions from the students, and reiterate this with the client.
- If there are parts of the project that will not be completed, have the client serve as a proxy for a documentation review, and encourage the client to give timely feedback.
- Prompt the client to request detailed scheduling information. Students can be very weak with identifying tasks for completion, and a detailed schedule review can go a long way toward quantifying exactly what needs to be done.

8. Scenarios for faculty training

A number of client scenarios have been created to illustrate use of the client assessment tool and to contextualize the success strategies described in the previous section. For reasons of confidentiality, the following scenarios are composites of case studies drawn from the pool of project data cited above.

8.1 SCENARIO—addressing a last minute client switch

A senior manager has been recruited into the scoping process for assessing different projects for your program. He is enthusiastic, and is well-grounded in the size of the projects that can potentially be completed, and is aware of the need for project fulfillment. He has not decided, however, on what member of his staff will serve as client liaison with the design team. A person is appointed after a commitment has been made and the semester started—there's no going back or refusing the project. The actual contact is non-responsive to student requests for a conference call. The easiest option is to call the senior manager, but you realize that if you do that, you run a risk of alienating the actual program contact. What do you do?

In this case, much is unknown about the actual client capabilities or disposition. Motivation appears to be low, because no contact has been made with the students. The recently assigned client is unlikely to be informed of the various value propositions about the capstone program. It is a good assumption that the client has an authoritarian v-meme. It therefore becomes imperative for the

professor to contact the client directly. If there is a delay of a week, it is actually recommended to contact the client with the students standing by, so that once contact is made, the students can make immediate arrangements to further the relationship. The first author has had many circumstances like this, where travel arrangements get made on the first contact with the assigned client.

Once the students visit, the natural Arc of the Project advises latency in the contact with the project client. Capstone instructors can use this time to contact the client again, and explain the Arc of the Project. Ask about the client's design process, and correlate the class design process with that of the sponsor, adjusting the class timeline if need be. Coach the students with templates as well as exemplars for the written project specifications and the preliminary design review.

Once the client has been informed of the course expectations, and seen the follow-through, there is often an exponential increase in interest, with the client becoming very involved in the final stages of the project. To later become highly involved. In more than one instance in this scenario, the first author has seen subsequent PDRs with an expanded list of stakeholders for the students to respond to. It is important to coach the students to not become discouraged with the client early on, and to maintain professionalism and positivity.

8.2 SCENARIO—cultivating the inexperienced engineer

A young engineer has been informed by their supervisor they are to act as the liaison between the student group and the company. Initial interactions between the instructor and the engineer appear to be positive. However, it becomes obvious after a few interactions after the specification is written that the young engineer is changing requirements in the specification in an arbitrary fashion. This is delaying the PDR for the students in your class. What do you do?

Often, young engineers from programs without a formalized design process instruction will not be familiar with the idea behind a gated design approach. One must then coach the client on how to have a good design process without confronting the client's lack of knowledge. In some circumstances, the engineer may be having problems adapting to their new work environment and may be bringing some of that frustration into their interactions with the students. Non-empathetic modes are the primary problem here, and the client will have to be coached on relational management as well as design process.

For individuals with authority issues, or a lack of knowledge, one must proceed very carefully. The best tack to take is one where the Arc of the Project

is presented as a student requirement, and your role as a client is to make sure students follow this because this is what the accreditation body/faculty consensus demands. Deferring authority to a neutral party is a great way to introduce the inexperienced client to the idea there might be a more systematic way to approach design.

Follow through with the students to make sure the quality of work meets your expected requirement, and track the process for the PDR by having the students request guidance from the client on what they would like to see during the PDR. This ensures the client's authority, which may be a bit shaky is not challenged. Usually, once the client sees that the project is going to be completed, they are then reassured their status will remain intact through solid student performance.

Additional coaching may be necessary in the final design phase to inform the client to not withhold information to the students. A phone call may be necessary to give insight on what students may or may not know.

Sometimes, issues arise with young clients of school rivalries with your home institution, or in the extreme, relational pathologies. Always discuss the fact-based circumstances with the assigned client. However, if problems persist, inform the client's supervisor in a manner that targets the informational needs of the students. Allow managers the flexibility to come to the conclusion that the appointed client is the problem.

Often, with older engineers, an individual will step forward that is extremely high ranking on the assessment scale, yet will have difficulty serving as a successful client. This is usually due to an unspoken desire for that individual to be a teacher, and construct activities for the students to do that the individual feels are helpful educationally. Such an individual is likely to be a communitarian, yet does not understand the necessary evolution students must pass through to create a valuable final product.

8.3 SCENARIO—accommodating the inner teacher

An older engineer who has been a successful mentor of individuals inside the company has volunteered to be the client for a project. This individual has never served as a liaison with a group of students, but has confided in you they would like to teach at a community college in the near future. Students in the group have made the specification trip, but are already questioning some of the work assignments the client is making, which are ancillary to the Arc of the Project. What do you do?

Often, such an individual will be involved from the class from initial commitment, to pre-scoping and through to the final completion. Pre-scoping, a

conference call, accompanied by a detail description of Arc of the Project is often necessary to orient such a sponsor. Reiterate students' previous coursework in techniques and have the client understand part of the class is for student to apply previous proficiencies as part of important confidence-building.

Be prepared to discuss pedagogical goals with the client, because that is their primary interest. Have a collaborative discussion with the client about the structure of the PDRs at their company, and modify your process to include their input. Discuss as well project closure, and any work a client may want that seems extraneous. As much as possible, using the Arc of the Project as a basis, fold the client's pedagogical desires into students completing the project. Emphasize the need for the client to not withhold information in the project final phases.

8.4 SCENARIO—managing the scope changer

An entrepreneur with a small workforce has heard about your program regionally, and wants to host a project in your capstone class. Their staff is small, and the entrepreneur seems primarily interested in completing some engineering work for a must-make prototype deadline. Because of various political pressures, you have no option but to take the project. Shortly after the PDR, the entrepreneur changes the scope to the students, but neglects to involve you in discussing the change. What do you do?

Of all the potential difficulties in student projects, the worst are those involving project scope change. As the instructor, you have agreed on something reasonable—yet this reasonable thing is changed beyond your control.

Some level of up-front explanation is useful in this circumstance. Small shops are often must-make-deadline driven, regardless of the assurances a priori. Explaining the Arc of the Project, as well as student requirements, at the beginning is very valuable for client management. Emphasize the short time students have to complete the project.

When the client changes scope, it is necessary for the instructor to contact the client and make sure there is a focused goal students can achieve in the context of remaining time. Often, the client will have a poor sense of the work necessary to complete various add-ons, and coaching the client often can entail running through a list of changes and assigning your best guess of completion times. At the same time, explore ancillary deliverables that could make up the larger value proposition. Is one of the deliverables the client desires a drawing package? A contract bid document? These types of sub-deliverables can be useful for students to deliver when scope changes make it impossible to complete the entire project.

Sometimes, clients (especially from small firms)

can simply become unreasonable. In that case, it is always best to not charge any money and release the client from any fiduciary requirement. Every business will have non-paying customers. The key is to minimize these in the context of the larger capstone operation. If this occurs, work on structuring the remaining experience for the students to be a positive one. There is no point in siding with the client and ruining the exit experience for the students.

9. Conclusions

Coaching strategies, aligned with the Spiral Dynamics model, have been formulated to facilitate client performance in the capstone ecosystem. These are derived from case studies involving 50 projects with in-depth project documentation by students and clients that were kept in a Basecamp system. These strategies were also augmented by the author's experience with more than 350 capstone projects that have been completed over the last twenty years. Essential client coaching lessons include the following:

- (1) Student development should be an explicit capstone project focus, but this should be built around an authentic project that is endorsed by a third party sponsor. If approached only implicitly, professional development is likely to remain stagnant. In order to develop authentic self (Performance v-Meme mindset), students need an authentic project, with real goals and third party expectations.
- (2) Clients are partners in facilitating student development. Clients need to begin their journey through the Arc of the Project as enlightened customers, moving toward a mentoring/consulting role in the latter half of the project. When this point is understood, this grows v-Meme Global Systemic development in the client as well, and will often provide a personal developmental incentive to not only help the students grow, but will increase client satisfaction and bring the client back for more project sponsorship.
- (3) Client knowledge, skills, and attitudes are varied and can be inventoried with the client assessment rubric. Assessing where a client is relationally at the start of the project can help the supervising professor develop an individualized coaching strategy that is maximally effective. For example, a client solely focused on the goal of project completion may not be sensitive to the need for mentorship of the students in building effective community.
- (4) There are naturalistic, high-leverage intervention points in client-student interactions and in

instructor-client mentoring. These revolve around pre-project scoping, the preliminary design review, and the detail design review. Understanding the relational growth goals for students at each of these specific times will maximize both student performance and emotional development.

- (5) Client scenarios are a tool for sharing both risk factors and success strategies related to instructor and client actions within the capstone ecosystem. The more understanding of the professional development process, conveyed anecdotally in the scenarios, the more effective the educational experience for the students and the greater the satisfaction of the sponsoring organization. When making a decision to coach the client, just as with students, correct classification and intervention on v-Meme development is an effective mentoring tool.

Acknowledgements—The first author would like to acknowledge the 60 corporate clients that have supported the Industrial Design Clinic over the 20 year period, as well as the Pacific Northwest National Labs for their generous support. The second author would like to acknowledge the 50 corporate clients that have supported the inter-disciplinary capstone program at the University of Idaho in parallel with the 22-year history of the end-of-the-year Design Expo that celebrates annual design accomplishment as well as professional growth.

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