A Systemic Model of Development: Strategically Enhancing Students’ Cognitive, Psychomotor, Affective and Social Development

Linda Vanasupa¹, Jonathan Stolk ², Trevor Harding³, and Richard Savage⁴

Abstract - The challenges of the 21st century create an imperative for engineering educators: to design learning experiences that result in engineering professionals with a sophisticated level of cognitive, psychomotor, social and affective development. We propose a tool for the design process. Our systemic model of development (SMD) is based on a large body of learning theory and empirical data. It maps the relationships among the major factors that influence learning in the form of a causal loop diagram. To demonstrate the value of the SMD, we compared the motivational profiles of a test group (36 students) who took an engineering course designed with the systems model of development to those of a quasi-control group (33 students) who took a conventional engineering course. The test cohort of students demonstrated significantly higher levels of intrinsic motivation (86% of a standard deviation, p=0.001) and identified regulation (53 of a standard deviation, p<0.001). Both types of motivation are key factors for self-directed learning.

Index Terms – self-directed learning, learning theory, motivation, holistic development

INTRODUCTION

The need for transformational change in engineering education has been well articulated in several recent publications¹-³, stating that current practices in engineering education do not impart the critical skill sets required of the 21st century engineer⁴, ⁵. The effective engineering professional of our global marketplace will need a host of new skill sets, including cultural sensitivity and agility in rapidly assimilating new information. There is also a necessity for a level of sophistication that goes beyond the traditionally-emphasized cognitive development. Competencies like “life long learning” have long topped the list of educational outcomes for engineering, but in a National Science Board-Sponsored Workshop, “Engineering Workforce Issues and Engineering Education: What are the Linkages?”, participants cited the need for a new skill set that includes teamwork, moral, ethical, and social development as well as life long learning and systems thinking skills⁶. These new competencies for the 21st century engineer, while they certainly draw upon cognitive development, also require higher levels of social and affective development—areas not usually emphasized in traditional engineering curricula.

Some investigators have made progress toward developing engineering students in these other domains. For example, the Engineering Projects in Community Service at Purdue University has been particularly successful through their civic engagement model of learning⁷. They and others have pioneered teaching and learning strategies that have strengthened students’ sense of social responsibility⁸-¹⁰. However, while some institutions have committed themselves to the goal of educating engineers for moral, ethical and social development (e.g., Smith College, Clarkson University, and the California Polytechnic State University), these initiatives are local. An awareness of how to redesign current engineering curricula to meet the changing educational needs could facilitate wide-scale progress.

Within engineering education, the traditional curricular approach has been to “outsource” the students’ broader development to “general education” courses. However, such approaches fail to recognize that effective development in these areas requires educational experiences rooted in the contextual details of engineering practice. Context plays two important roles in the moral and social development of students. First, it provides a motivating force that is necessary to actively engage students in their own development which subsequently leads to the building of cognitive structures within the moral domain. Second, it provides the opportunity to establish mental connections between these newly established moral cognitive structures with existing engineering-oriented cognitive structures. Without these connections, it is unlikely that engineering students will apply these new moral advances; instead seeing moral principles as mere abstractions. The absence of systematic methodologies for this development within courses traditionally viewed as “engineering courses” may stem from gaps in our knowledge of how the multitude of factors in the learning environment influence students’ social, affective and cognitive development.

¹ Linda Vanasupa, Materials Engineering, California Polytechnic State University
² Jonathan Stolk, Visiting Scholar from Franklin W. Olin College, stolk@olin.edu
³ Trevor Harding, Materials Engineering, California Polytechnic State University
⁴ Richard Savage, Materials Engineering, California Polytechnic State University

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We have attempted to clarify these connections through a systemic model. The model makes explicit the connections that influence students’ development to enable faculty to design learning environments and experiences that foster deeper learning and broader skill development. In this paper, we present this systemic model of development in the form of a map of the relationships among various constructs (e.g., motivation, interest), learning influences (e.g., active learning, an understanding of the broader context) and a learner’s cognitive, psychomotor, affective and social development. We first review the empirical and theoretical underpinnings of the model. This is followed by a discussion of how the model can be used as a course design tool. We then present data showing that a cohort of 36 engineering students who took a course designed with our systemic model of development scored higher in factors linked to self-directed learning, retention, teamwork and greater use of cognitive strategies for learning than a comparable cohort (33 engineering students).

THE SYSTEMIC MODEL OF DEVELOPMENT: ITS THEORETICAL AND EMPIRICAL BASES

I. The internal drive for learning

It is well-recognized that the learning process is constructive, requiring an active role by the learner. That is, while teachers can provide information, structure activities, and illuminate concepts, learners must initiate, monitor and regulate the process of incorporating the ideas into their mental models. Pintrich referred to this “active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate and control their cognition, motivation and behavior, guided and constrained by their goals and the contextual features in the environment” as self-regulated learning or self-regulation [11]. Self-regulated learning consists of three components: 1) metacognitive strategies (planning, monitoring and modifying one’s cognitive development); 2) time-management on academics tasks; 3) employment of strategies to learn and understand material [12]. Clearly, self-regulated learning or “life-long learning” is one of the end-goals of engineering education, but how can this core competency be developed through the curriculum?

Not surprisingly, motivation is one of the foundational components of self-regulated learning [13-16]. That is, higher motivation—and in particular, the types of motivation which are associated with the learner’s internalized value of the activity—results in a higher degree of self-regulation in the learning process [17]. Students’ interest in the material, or internal valuation of the material has also been found to influence their motivation to learn it [17-19]. Self-regulation also requires autonomy, or freedom to act independently without external control. These three attributes (motivation, interest and autonomy) are positively correlated with one another. That is, changes in one (e.g., increases) results in the same type of changes in the others.

Within our systemic model of development (SMD), we cluster these three attributes—motivation, interest, and autonomy—and map their empirical relationships into what we call a learner’s internal drive for development, as shown in Figure 1. This internal drive is central to one’s development; symbolically, it resides at the center of development in the cognitive, psychomotor, social and affective domains as shown. The strength of the learner’s internal drive for their own development derives from the causal relationships between interest, motivation, and autonomy. For example, an increase in interest increases motivation; both result in an increase in an autonomous exercise of self-regulation during the learning process. Another way of looking at these relationships is that providing greater autonomy in the learning process (leads to increases in interest and motivation[20]. The “s” at the arrowheads indicates that changes occur in the same direction; a decrease in interest decreases motivation and self-regulated learning. The “R” in the center of the loop indicates that changes in these attributes Reinforce one another. That is, increases (and decreases) to the internal drive tend to self-perpetuate, rather than balance one another. In reality, it is not clear which of the three start the process of one’s internal drive for learning, nor is it critical. The importance of this simplified representation of the learner’s internal drive for learning is that these work together in a reinforcing way.

![Internal Drive for Learning](image.png)

FIGURE 1

Internal Drive for Learning. It resides at the center of one’s cognitive, psychomotor, social and affective development. The strength of the internal drive comes from the causal links between interest, motivation and self-regulation.

We should note that this 2-dimensional version of the model does not show all factors that contribute to one’s learning. For example, familial influence, cultural norms and other social pressures are not mapped in the model, but research shows that they do play a role in forming one’s interest in and motivation for learning. In a real sense, these factors underlie one’s internal drive for learning. Symbolically, we would represent these factors and others, like self-efficacy (the belief that one is capable of achieving...
their goals) as shown in Figure 2, feeding the internal drive circle from below. This reflects the empirical data that shows that higher degrees of self efficacy are correlated with more interest and self-regulation in learning, and teachers who are empathetic and who actively support student autonomy positively affect student engagement [21, 22].

Also, research shows that learning environments strongly affect what we are calling students’ internal drive for learning. In other words, how engineers are taught affects the engineers’ resulting development at least as much as what they are taught. We have chosen to omit some of these individual influences, because the model can sufficiently account for them. As an example, teachers who treat students disrespectfully and/or are controlling have a negative influence on motivation and interest [23]. These relationships can be explained in the systems model by recognizing that a faculty’s controlling behavior decreases students’ freedom of choice (lowers autonomy), thereby lowering motivation and interest in learning. Teachers who treat students respectfully and encourage learning responsibility can have a positive effect on motivation, interest and other factors that bolster their internal drive.

II. Developing mastery through engaging the internal drive

To relate an individual’s internal drive to other constructs (such as mastery of one’s discipline), we draw upon self-determination theory. It provides a framework for understanding the interplay between these internal drives (our grouping of interest, motivation and autonomy) and intrinsic tendencies for developmental growth and inherent psychological needs [24]. Self-determination theory implies that meeting the learner’s psychological need for relatedness, i.e., a sense of belonging, personal support and security in the learning context, enables a greater degree of motivation and self-regulation [25-27]. Additionally, providing autonomy increases one’s engagement in their development [25], as do greater degrees of interest and motivation [28, 29]. The empirical data also show that a greater degree of engagement or active learning results in higher mastery [12, 30-32]. The simplest form of this principle is the adage, “Practice makes perfect.” Here, mastery is broadly defined to include both a sense of mastery and/or actual proficiency. In our systemic model of development, we indicate these relationships with arrows as shown in Figure 3. As in the previous figures, the “s” sign indicates that changes of the two constructs occur in the same direction; an increase (decrease) in one quality will cause an increase (decrease) in the other. Note that the arrows in and out of the internal drive circle treat the internal drive qualities (interest, motivation and autonomy) as one construct, internal drive for learning. This figure shows that another reinforcing loop, indicated by “R,” is formed by the internal drive, engagement/active learning and mastery. The spatial position of the constructs on the SMD reflects their primary developmental domains. For example, mastery in engineering draws heavily from the cognitive and psychomotor domains, so it is placed at their intersection. Relatedness falls largely within the social domain, whereas effective engagement/active learning derives from a combination of the cognitive-psychomotor and social-affective development.

III. Moral and ethical development through engaging the internal drive

To address the connections between moral/ethical reasoning, we draw upon the theoretical framework proposed by Kohlberg [33]. He proposed that moral develop occurs through a process where an individual must actively resolve a conflict between their personal values and a conflicting broader context. For example, presume an engineering student internalizes their identity as an engineer, along with the engineering profession’s ethics creed: a commitment to use their professional knowledge for the welfare and betterment of society. When participating in the design of engineering products that arguably violate their creed (e.g., low-mileage vehicles that produce excessive amounts of greenhouse gases), they have the opportunity to develop ethically and morally if they actively resolve of this cognitive dissonance. This leads to the causal relationships mapped in
the SMD shown in Figure 4. Within this figure, we see another reinforcing loop: as one develops a greater understanding of the broader context, they develop morally. A greater moral and ethical development also results in a greater understanding of the broader context.

Greater ethical/moral development has also been observed through studies involving service learning [9, 34, 35], underscoring the importance of understanding the broader context (i.e., a knowledge of the connections between what is being studied and the larger impacts on society) and engagement/active learning.

Understanding the broader context in the engineering curriculum also promotes interest (and retention) of female engineering students [36, 37]. The ability to make sense of the broader context, or “big picture,” is a skill practiced through systems thinking [38]. That is, greater proficiency in systems thinking promotes a fuller understanding of the broader context (and vice versa). We propose that increases in systems thinking will also result in higher mastery. Our rationale is that the cognitive development required by mastery is aided through one’s ability to connect the concepts to related issues. Taken together, these relationships result in a systemic model of development shown in Figure 5. For reference, the terms used in the model are defined in Table 1.

TABLE I
WORKING DEFINITIONS OF THE CONSTRUCTS USED IN THE SYSTEMIC MODEL OF DEVELOPMENT

<table>
<thead>
<tr>
<th>Construct</th>
<th>Working Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mastery</td>
<td>Competence. It consists of conceptual understanding and proficiency in applying that knowledge.</td>
</tr>
<tr>
<td>Moral and ethical</td>
<td>Ability to recognize and evaluate moral/ethical dilemmas and to decide upon and follow through with moral/ethical actions.</td>
</tr>
<tr>
<td>development</td>
<td></td>
</tr>
<tr>
<td>Systems thinking</td>
<td>The ability to see the whole and establish a framework for seeing inter-relationships rather than individual things—for seeing patterns of change rather than static conditions</td>
</tr>
<tr>
<td>Engagement/Active</td>
<td>Active involvement in the learning process. This could occur at many levels, such as intellectual, psychomotor, emotional and social</td>
</tr>
<tr>
<td>learning</td>
<td></td>
</tr>
<tr>
<td>Relatedness</td>
<td>Feeling of belonging, personal support, and security in their school relationships</td>
</tr>
<tr>
<td>Understanding the</td>
<td>A knowledge of the connections between the subject that is being studied and its larger implications for one’s self and society</td>
</tr>
<tr>
<td>broader context</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Using the Systemic Model of Development in Course Design**

Although not exhaustive, the model provides opportunities to design learning experiences to strategically target students’ development. Advancing in development of a construct is not indicated on the model, per se. The model simply shows how several factors in the learning environment interact. When viewing the model, developmentally advancing in a construct such as mastery would equate to moving along an axis centered on mastery and coming out of the plane of the paper toward the viewer. The highest order of development for

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To use the model in course design, an instructor could first identify the targeted type of development. For example, presume the instructor desired to increase the students’ moral and ethical development. Let’s first consider how one would approach this conceptually. (In the following paragraph we will provide a detailed example.) As shown in Figure 5, there are several constructs that are ultimately connected to moral and ethical development. The strategy for the instructor would be to design assignments and structure the learning environment to leverage the natural causal relationships that lead to greater moral and ethical development. Figure 6 depicts a subset of the constructs that feed into moral and ethical development.

![Causal Loop Diagram](image)

**FIGURE 6**

POSSIBLE STRATEGIC PATH TO INCREASE MORAL AND ETHICAL DEVELOPMENT.

It shows that greater understanding of the broader context and engagement/active learning lead to moral and ethical development. It also shows that a greater degree of systems thinking will enhance understanding of the broader context. Because changes in the constructs within the path are positively correlated to one another (indicated by the “s” near the arrowheads), the instructor should attempt to increase these constructs during the learning experience. In essence, Figure 6 illuminates a strategy that the faculty could use to ultimately increase students’ moral and ethical development.

As a further illustration, we describe how the systemic model relationships were used to design a sophomore-level course on nanotechnology, biology, ethics and society. Using the strategy shown in Figure 6 required course features to increase proficiency in systems thinking, to enhance understanding of the broader context of the material, and employ active learning. This particular course was structured with a modified version of the team-based learning strategy developed by Michaelsen, Bauman-Knight and Fink [39]. At the beginning of the quarter, students were openly and randomly assigned to formal, six-person teams based on their strengths. The formal teams facilitated cooperative learning in the in-class activities that were assigned throughout the term. In reference to the systemic model of development, we utilized engagement/active learning throughout. The course met in two-hour blocks, twice a week for ten weeks. The teams’ time together was structured to complete common team goals to increase their sense of relatedness. One of the ways that we emphasized an understanding of the broader context and systems thinking was by highlighting the interconnectivity of public policy, health and safety, technology, and society throughout the course activities. One activity involved having the teams create a causal loop diagram that illustrated the links between government policies that subsidized corn production, corn sugar content in foods, per capita corn sugar consumption, incidence of obesity in the U.S. and incidence of type II diabetes in the U.S.. These types of diagrams, like the systemic model of development, require the creators to understand the causal relationships between the factors. The causal loop diagrams provide a visual image of the systemic nature, linking seemingly disparate events as public policy and the incidence of type II diabetes.

In another class activity, individuals were required to read a case study on an industrial accident involving polyvinyl chloride before coming to class. The teams were then given data from the Environmental Protection Agency’s Toxic Release Inventory for the precursors for poly vinyl chloride production. They were also given the National Society of Professional Engineer’s Code of Ethics and asked to identify the end point in a product life-cycle where the design engineer is no longer responsible for the health and safety of the public.

In this activity, the Code of Ethics served to provide an understanding of the broader context of their role in society. The activity provided an opportunity for students to debate the issues within their teams. Through the debate (active learning) and the need to justify an answer with an embedded value proposition, we created the situational requirements that Kohlberg described as necessary for moral development[33]. They were told that there was no right answer, but they needed to justify their answer. Incidentally, each of the six groups, without any input from the instructor, converged on the same answer. The rationale was best articulated by one of the teams, “Because a product can be inherently dangerous to the health and safety of the public at all stages of its life cycle and the code of ethics states that we are to hold paramount the health and safety of the public, there is no endpoint for a design engineer’s responsibility.” This conclusion demonstrated an advanced degree of moral reasoning that connected the design engineer’s choices to the impact on society. The important aspect of this exercise, we note, is not the exact conclusion, but the process of finding resolving their actions with their values.

Thirty two students in the course described above reported that understanding the broader context increased their interest in the science and motivation to learn the material[40] (Four did not complete the survey). They also reported a higher level of self-regulation (specifically, reading assigned journal articles) in preparing prior to class compared to their other courses. We note, however, that the course
grading structure (which they collectively negotiated) may have also strongly influenced their choice to read the materials.

RESULTS FROM A JUNIOR-LEVEL MATERIALS ENGINEERING COURSE

Our intention in creating the systemic model of development was to utilize it as a design guide for improving learning. Our intent was not to prove or verify the connections explicit in the model, since these connections are mapped according to a wealth of empirical data and learning research, but to leverage the known connections to design learning experiences that are more effectual.

Our research hypothesis was that students exposed to a learning experience designed with the aid of the systemic model of development would exhibit higher levels of targeted constructs than a comparable peer group exposed to conventional engineering education (i.e., lectures and laboratories). For the scope of this paper, we have focused on the differences in students’ motivation profiles as measured through the Situational Intrinsic Motivation Scale (SIMS) developed by Guay, Vallerand and Blanchard [41] and based on Deci and Ryan’s self-determination theory [17, 42].

The SIMS was designed to assess four constructs, intrinsic motivation, identified regulation, external regulation and amotivation. Intrinsic motivation operates when one engages in an activity for the activity’s sake (e.g., I think this activity is interesting); Identified regulation is when one values it as a means to an end (e.g., I believe this activity is important for me); external regulation is associated with either trying to earn a positive outcome or to avoid a negative one (e.g., Because I am supposed to do it); amotivation occurs when one perceives a disconnect between engaging in the activity and the outcome (e.g., There may be good reasons to do this activity, but personally, I don’t see any.). These four types of motivation fall on a continuum of high to low levels of self-determination and self-regulated learning [41]. In other words, those motivated by intrinsic motivation perceive themselves as freely choosing to engage in the activity. Identified regulation and external regulation are both extrinsic types of motivation, where the behavior is regulated by an external reward (such as helping one to be a better engineer [identified regulation] or getting a good grade [external regulation]).

I. Methodology

This study involved two cohorts, a “test” cohort (36 materials engineering majors) and a “quasi-control” group (33 engineering majors of various fields). All students were engineering majors at the California Polytechnic State University (Cal Poly) at academically comparable points in their major at the time of the assessment (the end of Fall quarter of their junior year). For the test group, the intervention consisted of a conversion of their junior materials engineering course sequence to a project-based learning mode, designed with the principles in the SMD. There was no intervention for the quasi-control group; presumably, this group experienced the traditional lecture and laboratory modes in the engineering major courses. We note, however, that engineering programs at Cal Poly are laboratory intensive. Typically, the time spent in the laboratory mode is 40-50% of the total time spent in the engineering major courses. Engineering students entering Cal Poly do so with an SAT score between 1100 and 1300. Roughly 80-90% of engineering graduates began at Cal Poly as freshmen. By the end of their sophomore year, the students of differing engineering majors who began at Cal Poly have about 80-88% of their education in common. While the general education course sequence is the same across Cal Poly engineering curricula, major engineering courses (e.g., electrical engineering courses for electrical engineers) begin to diverge during the junior year. During the junior year, major engineering courses also comprise about half of the units taken by the students. At the time of this study, attrition rates and graduation rates across the engineering programs were not significantly different, so it is reasonable to conclude that students in the test cohort and quasi-control are academically similar and have taken ~80-88% of the same courses up through their sophomore year. Gender and ethnicity demographics were not collected from the quasi-control and test cohorts. Based on Cal Poly’s institutional data, however, it is likely that both groups consisted of fewer than 20% females and were primarily Caucasian or Asian-American males, and fewer than 10% Hispanic.

At the end of the first quarter of their junior year engineering courses, the test and quasi-control cohorts completed the 16-question Situational Intrinsic Motivation Scale survey instrument [41]. This particular instrument asks the respondent to read a statement and circle a response that best describes why they are engaged in a particular activity (in this case, learning in their major engineering courses) on a 7-point scale. Examples of some of the statements include Because I think this activity is interesting; Because it is something that I have to do; Because I believe this activity is important for me. The responses that they chose from were 1-corresponds not at all; 2-corresponds very little; 3-corresponds a little; 4-corresponds moderately; 5-corresponds enough; 6-corresponds a lot; 7-corresponds exactly. Field tests of the SIMS by Guay, Vallerand and Blanchard[41], indicate good internal reliability and construct validity.

Students in the test group completed the surveys as part of a battery of assessments at the end of their materials engineering course. Those in the quasi-control group were solicited via electronic mail on the basis of their similarity to the test group (engineering students completing a junior-level course in their major). They completed the survey voluntarily in exchange for free software. We note, however, that fewer than half the students picked up the software CD, so the software offer may not have been a motivating factor for those completing the survey. The two groups of students (the test group and the quasi-control) were not tested prior to the course. However, due to their similarities, it is reasonable to attribute differences in their responses regarding their
motivation in their major engineering course to their experience in the course itself.

The SIMS was analyzed using confirmatory factor analysis based on the four factors identified by Guay, Vallerand and Blanchard[41]. The internal consistency of scales was measured using Cronbach’s alpha. Scale scores were calculated through a weighted sum of the scale items where the weights are based on the factor loading for each particular item.

II. The Learning Experience for the Test Cohort

For the course involving the test cohort, our goal was to increase mastery in the area of design, teamwork, and self-directed learning. We also had a number of learning outcomes for physical metallurgy and electronic properties of materials that we achieved through some assigned readings coupled with in-class team activities relating to the projects. Figure 7 shows that targeted constructs in bold and the constructs that we attempted to strengthen in the course design to achieve the target constructs in italic.

![Targeted Constructs and Factors within the Test Course](image)

This course met everyday for a total of 12 hours per week. Very few lectures were given in the 10-week period. Those that were given were usually 20-30 minutes long. Approximately 90% of the in-class time was devoted to team-based project activities. The three instructors, Savage, Stolk and Vanasupa, primarily served as coaches, helping individuals and teams think through points of confusion. The details of the projects are described elsewhere [43]. In brief, students had 10 weeks (120 hours of in-class time) to complete the two projects while working in formal teams (i.e., teams that lasted the entire course). The team structure was designed to promote relatedness. The Comprehensive Assessment of Team Member Effectiveness Web site, www.catme.org, was used mid-course, as a means of helping teams operate more effectively. We infused the course with a number of carefully-designed learning activities (engagement/active learning). In one project, they were to design, prototype, fabricate and market a cast metal object to their colleagues, paying particular attention to sustainability issues (environmental concerns, social equity in the product life cycle) and the materials science. The design decisions and choice of project was left to the student teams to allow greater self-regulation through autonomy in the learning process (i.e., allowing the students to exercise choices in their project). The link to sustainability issues constituted understanding the broader context. These constraints were somewhat artificially imposed due to our learning objectives around metallurgy, systems thinking and broader contextual issues. The second project involved designing, building and testing a fiber optic spectrometer. Many activities within the fiber optic spectrometer were intended to promote systems thinking. We imposed several constraints due to equipment limitations and our learning goals. As mentioned, 90% of the in-class time was devoted to active learning around their projects or the materials science and engineering related to their projects. Table 2 summarizes the attributes that we designed into the course and provides some detail on their implementation.

<table>
<thead>
<tr>
<th>Design attribute</th>
<th>Details of implementation</th>
<th>Targeted outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems thinking and Understanding the broader context</td>
<td>Each team was required to address their projects as an engineered system. They were also required to articulate and assess the impact of design choices on the environment, address health and safety considerations, social justice issues related to material choices.</td>
<td>Increased motivation for learning, greater awareness of ethical considerations related to design choices</td>
</tr>
<tr>
<td>Active Learning</td>
<td>Teams completed two projects in which they were required to design, build and test a product (a cast metal object and a fiber optic spectrophotometer).</td>
<td>Greater mastery in engineering design, greater sense of mastery as an engineer</td>
</tr>
<tr>
<td>Self-regulation</td>
<td>Teams were given autonomy in negotiating the grade weighting scheme for the course. They were also allowed to select the product that they wanted to prototype for the cast metal object and allowed to make all decisions related to the design, fabrication and testing of their products.</td>
<td>Increased intrinsic motivation (interest and motivation), greater mastery of self-directed learning skills</td>
</tr>
<tr>
<td>Relatedness</td>
<td>Formal teams and course work revolving around cooperative learning</td>
<td>Greater mastery of self-regulated learning skills (specifically, utilization of peers as learning resources)</td>
</tr>
</tbody>
</table>

III. Test Group Scored Significantly Higher in Intrinsic Motivation and Identified Regulation

The confirmatory factor analysis results for the test group on the SIMS are shown in Table 3 below. The four major
columns in Table 3 indicate the four factors within the SIMS scale: intrinsic motivation (IM), identified regulation (IR), external regulation (ER) and amotivation (A). The item number corresponds to the number of the statement in the SIMS (see Appendix for a reproduction of the SIMS statements). The factor loading is a measure of how strongly the particular item influenced the factor, with 1.0 being the highest value. The high values of Cronbach’s alpha (α) (maximum of 1.0) for each factor indicate very good internal consistency in the responses. A Cronbach alpha greater than 0.7 is an indication of very strong internal reliability (a measure akin to repeatability in statistical measurement studies), which is consistent with the results of Guay, Vallerand and Blanchard.[41]

### TABLE 3

**RESULTS OF THE CONFIRMATORY FACTORY ANALYSIS OF THE SITUATIONAL INTRINSIC MOTIVATION SCALE (SIMS) FOR THE TEST GROUP. ITEM NUMBERS CORRESPOND TO THOSE IN THE APPENDIX FOR THE SIMS QUESTIONNAIRE.**

*Did not contribute significantly to the scale and dropped from the computation of Cronbach’s alpha for the particular scale item.*

<table>
<thead>
<tr>
<th>Intrinsic Motivation (α = 0.859)</th>
<th>Identified Regulation (α = 0.711)</th>
<th>Extrinsic Regulation (α = 0.837)</th>
<th>Amotivation (α = 0.852)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item #</td>
<td>Factor Loading</td>
<td>Item #</td>
<td>Factor Loading</td>
</tr>
<tr>
<td>-------</td>
<td>----------------</td>
<td>-------</td>
<td>----------------</td>
</tr>
<tr>
<td>5</td>
<td>0.812</td>
<td>6</td>
<td>0.854</td>
</tr>
<tr>
<td>13</td>
<td>0.610</td>
<td>14</td>
<td>0.775</td>
</tr>
<tr>
<td>9</td>
<td>0.807</td>
<td>10</td>
<td>0.688</td>
</tr>
<tr>
<td>1</td>
<td>0.709</td>
<td>2*</td>
<td>0.596</td>
</tr>
</tbody>
</table>

Students in the test group (N=36) scored significantly higher in intrinsic motivation (IM) and identified regulation (IR) compared to the comparable students of other engineering majors (N=33). The difference is large and statistically significant in both cases (IM: d=0.86, where d is the difference of the mean scores of the test group and the quasi-control group divided by the standard deviation, p=0.001; IR: d=0.53, p=0.001).

We note that the SIMS is based on a particular situation and respondents were directed to complete the survey based on their motivation in their engineering course in their major. Because Cal Poly’s engineering students share much of their first two years and the SIMS questionnaire was focused on engaging in the learning in the junior-level engineering course, it is reasonable to attribute the higher scores in IM and IR of the test group to the differences in their learning experiences in their major courses.

Intrinsic motivation has been repeatedly associated with positive learning outcomes, such as self-regulation of cognition and effort [13-16] and a greater enjoyment in learning (see Vallerand[44], 1997 for a review). Identified regulation, which can be thought of as a type of motivation that comes from valuing the activity, has been shown to promote students use of cognitive strategies in the learning process[12]. In short, both IM and IR act as drivers for one’s cognitive engagement and subsequent learning. In theory, learners who have motivation profiles that are heavily weighted toward IM and IR should be more engaged in the learning situation and more effective at self-regulation in the learning process.

We note that the SIMS refers to a particular situation. In other words, the context in which the learning occurs strongly influences students’ motivation profile and ultimately their engagement and self-regulation around learning. This underscores the importance of carefully designing the learning experience. That is, it is not just what we teach, but how the material is taught, which influences the learning, as emphasized by Bransford et al. [19].

### CONCLUSIONS

We have proposed a systemic model of development based on established learning theories and empirical relationships. This model addresses development within cognitive, psychomotor, social and affective domains and proposes causal relationships between the internal drivers of an individual’s development in these domains and attributes of the learning experiences. A course was designed using the principles in the systemic model of development with the aim of increasing students’ readiness for self-directed learning. Compared to a quasi-control peer group, students in the test group scored significantly higher for two positive motivational factors: intrinsic motivation and identified regulation. Both of these qualities have been shown in other studies to factor strongly into students’ abilities for self-regulated learning. The primary difference in these groups was that the test group experienced an engineering course designed by the principles of the systemic model of development. The results underscore the need for us as faculty to be mindful of how the material is taught in engineering courses. As engineering educators grapple with questions of how to best retain students and prepare engineers for the 21st century, the results of this study demonstrate promising evidence that our systemic model of development can assist faculty to design courses to strategically target the development of constructs within the cognitive, psychomotor, social and affective domains.

### ACKNOWLEDGMENTS

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### REFERENCES


APPENDIX

Reproduction of the items on the Situational Intrinsic Motivation Scale from the original by Guay, Vallerand and Blanchard[41]. Respondents were asked to choose the degree to which the statement best fits the reason why they were engaged in the course projects. The choices were Not at all (1), Very little(2), A little(3), Moderately (4), Enough (5), A lot (6), Exactly (7).

The original SIMS wording for the responses, quoted in the body of the paper’s text, were slightly modified for clarity. The rewording did not affect the reliability of the results as evidenced by the Chronbach alpha values for each scale.

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Codification key: Intrinsic motivation: Items 1, 5, 9, 13; Identified regulation: Items 2, 6, 10, 14; External regulation: Items 3, 7, 11, 15; Amotivation: Items 4, 8, 12, 16.