AC 2008-1596: ENGINEERING STUDENTS' CONCEPTIONS OF SELF-DIRECTED LEARNING

Jonathan Stolk, Franklin W. Olin College of Engineering

John Geddes, Franklin W. Olin College of Engineering

Mark Somerville, Franklin W. Olin College of Engineering

Robert Martello, Franklin W. Olin College of Engineering

Engineering Students' Conceptions of Self-Directed Learning

Abstract

Researchers have developed numerous theories and developmental models to describe self-directed learning, lifelong learning, and self-regulated learning. The literature includes a large body of research that illustrates the cognitive, metacognitive, motivational, affective, and behavioral attributes of self-directed learners; the influences of social and physical environment on self-directed learning development; and the roles of self-perceptions, causal orientations, learning conceptions, and demographics in determining certain self-directed learning responses. But how do undergraduate engineering students characterize and critique self-directed learning? This paper evaluates the responses of engineering students to questions regarding the definition of self-direction and the primary positive or negative factors contributing to their self-directed learning experiences. We find that undergraduate students at all levels are able to identify positive and challenging aspects of self-directed environments, and the emergent themes from the qualitative student responses map well onto theoretical frameworks for self-direction and self-regulation. Results are discussed in terms of pedagogical issues to consider when designing curricular experiences aimed at development of self-directed learning competency.

Introduction

Importance of self-directed learning

Calls for educational reform emphasize the need for new student-centered learning approaches that aid development of broader skills and attitudes to complement traditional knowledge acquisition.[1,2,3,4] A capacity for lifelong learning is often identified as a critical outcome for educational systems, and many assert that a self-directed learning (SDL) approach best facilitates the deep conceptual understanding and learning process engagement that enable individuals to flourish in ever-changing contexts. ABET and other organizations have recently asked educators to promote the development of students' lifelong learning skills through their curricula,[5,6] but calls for self-directed learning approaches are not new. In 1969, Carl Rogers articulated the need for flexible, independent learners:

> "Teaching and the imparting of knowledge make sense in an unchanging environment. This is why it has been an unquestioned function for centuries. But if there is one truth about modern man, it is that he lives in an environment which is *continually* changing…We are, in my view, faced with an entirely new situation in education where the goal of education, if we are to survive, is the *facilitation of change and learning.* The only man who is educated is the man who has learned how to learn; the man who has learned how to adapt and change; the man who has realized that no knowledge is secure, that only the process of *seeking* knowledge gives a basis for security." [7]

Education literature includes extensive discussion of the qualities and competencies of effective self-directed learners, and of student attitudes toward self-directed learning.[8,9,10] For example, Candy describes self-directed learners as individuals who are curious, motivated, disciplined, reflective, analytical, persistent, responsible, flexible, interpersonally competent, creative, and independent. Candy also notes that self-directed learners possess skills in information seeking and retrieval, knowledge about their learning processes, and evaluative capacities. Most engineering educators agree that these skills are important for success in today's technology-centered environments with their ever-expanding information bases, and that self-directed learning skill building in students will encourage the developmental patterns required for lifelong learning. Designing learning environments that foster student growth in these areas, however, is not a simple task. With its introduction of lifelong learning as a required outcome for all engineering graduates, ABET exposed major deficiencies in the approaches of conventional engineering curricula and illuminated the fact that conventional approaches may induce dependency rather than autonomy in learning. Educators now recognize that students' development of a capacity for self-directed, lifelong learning is critical for their success in today's global engineering environment, but the details of how we may best engage students in SDL (and eventually lifelong learning) still pose a substantial challenge. To effectively promote SDL, faculty need to develop skills in facilitating pedagogies that engage students in self-direction, a sensitivity to and understanding of student attitudes and behaviors in SDL settings, and knowledge of the roles that curricula can play in aiding students' SDL development.

Defining Self-Directed Learning

One of the greatest challenges associated with self-directed learning lies in its definition. Often engineering educators consider it as a single skill that individuals either have or lack. In reality, the development of SDL aptitude involves a complex interplay among nearly every aspect of human development. Individuals become self-directing through mastery of a broad range of skills, attitudes, and knowledge that enables construction of understandings and management processes for their thoughts, motivations, actions, and interactions with their learning environment.[11,12,13,14] Self-directed learners are like the self-regulated learners Zimmerman describes in that they are "metacognitively, motivationally, and behaviorally active participants in their own learning."[15] In addition to masters of learning processes, self-directed learners are self-starters, with intention to develop and conceptions of themselves as highly capable learners.[16,17] As Rogers notes, self-directed learners possess positive self-regard, a self-actualizing tendency, and openness to experience.[7,18]

Cognitive and metacognitive factors in SDL include students' abilities to recognize needs, develop strategies for planning, monitoring, and adapting learning processes, reflect on their cognitive processes, and engage in accurate self-evaluation of performance or mastery. [12,19] **Motivational** factors related to SDL reflect students' self-efficacy, perceptions of choice and control, task interest, perceived task value, anxiety control, and affective responses to the learning experience.[12,20] **Behavioral** components of self-directed learning include time and effort planning and management, mechanisms for attention focusing, and appropriate attribution of outcomes to behaviors. **Contextual** aspects of SDL encompass a variety of social and environmental factors related to students' responses to the freedoms and constraints of the educational setting. In courses, these may include the management of peer relationships,[21,22] interactions with physical resources,[19,23] and responses to the instructor's roles, styles, and requirements.[24,25,26] To navigate a SDL experience, learners must situate themselves in their environment and continually modify their strategies in response to environmental stimuli.[27]

Motivational, cognitive, behavioral, and contextual factors are clearly interrelated, and successful development of SDL skills relies on a complex balancing of these factors in the classroom. For example, much is known about the relationship between student self-direction and motivation, and about the importance of fostering positive student attitudes and behaviors for engagement in SDL environments. Autonomy has been shown to increase students' intrinsic motivation, self-efficacy, and perceptions of task value,[28,29,12,19] and use of cognitive and metacognitive strategies for learning and adaptive motivational strategies.[30] Black and Deci further demonstrated that autonomy-oriented students had higher perceived competence, higher interest and enjoyment, and lower anxiety and grade-focused goals.[24] Instructor support and a healthy classroom climate are critical components of self-directed learner development.[7] Studies have shown that students' positive perceptions of their assigned tasks and instructors' autonomy support can lead to increases in intrinsic motivation, self-regulation, perceived competence, interest, engagement, and academic performance.[30,31]

Self-directed learning clearly offers many benefits to personal and academic growth. At the same time, SDL is known to sometimes create obstacles to growth. In transitioning from a traditional to a SDL mode, students need to embrace unfamiliar roles and responsibilities, including engagement in higher level cognitive processes as goal identification and self-reflection. The transition can produce student anxiety arising from uncertainties in goal-setting; difficulties in acquiring resources; failure to internalize learning goals; dissatisfaction with the classroom climate; inaccurate prediction or management of time and effort; disparities between expectations and outcomes; inability to self-monitor cognitions without external validation (i.e., uncertainties about learning the "right stuff"); failure to coordinate strategies and contextual factors (e.g., teammates); and incorrect predictions of learning.[32,33,34] While some students might benefit from the experience of overcoming these challenges, the responses these factors evoke may have significant deleterious effects on the social environment and situational motivation.

Frameworks for Studying SDL

The educational literature describes many different learning frameworks for self-directed learning based on different constructs or perspectives. For this investigation, we focused on two models for self-regulated learning proposed by Zimmerman[19] and Pintrich.[35,36] The Zimmerman and Pintrich self-regulated learning models are strikingly similar. Both models are based on a social-cognitive perspective that assumes learners are active, constructive participants in the learning process. In the self-regulated learning experiences described by the frameworks, 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." The Pintrich model (Table I) describes four phases of self-directed learning: (1) forethought, planning, activation, (2) monitoring, (3) control, and (4) reaction, reflection. Within each of these phases, Pintrich illustrates four possible areas for learner self-regulation: cognition, motivation, behavior, and context. Depending on the learning experience, students may simultaneously engage in more than one phase, and may attempt to gauge or regulate one or more areas of functioning.

The Zimmerman model describes three phases of self-regulation: (1) forethought, (2) performance/volitional control, and (3) self-reflection. The performance/volitional control phase in this model combines aspects of Pintrich's forethought, planning, activation and monitoring phases. Rather than providing a detailed description of areas for self-regulation, Zimmerman describes self-regulatory sub-processes (e.g., task analysis, self-motivation, self-control, and self-judgment) for each of his three phases. Zimmerman describes the three self-regulatory phases as cyclical, with forethought occurring prior to control efforts, and self-reflections occurring after control efforts.

Table I. Pintrich conceptual framework for studying self-regulation.[36]

Phases of Self-Regulation	Areas for Self-Regulation
Forethought, planning, activation	Cognition
Monitoring	Motivation
Control	Behavior
Reaction, reflection	Context

Since both the Pintrich and Zimmerman models describe *self-regulated*, rather than *self-directed*, learning processes, they presume that a learner is initially situated within an academic learning context such as a school or classroom. As such, these models assume a set of starting conditions to the learning experience: a learning need is identified, the learning opportunity is assessed, learning topics are selected, the social environment is set, and individuals are behaviorally and motivationally positioned within the learning context. These assumptions work well when considering self-regulatory processes within typical courses and curricula, but they do not necessarily consider some processes that may be required at the onset of more exploratory learning experiences such as independent study, research, or open-ended design activities. In these situations an individual's *intention* to learn – including self-actualizing tendencies, positive self-regard, openness to experience, and choice of and positioning within particular environments – becomes the critical element of the self-directed experience.

This study presents a framework for self-directed learning based primarily on the phases and processes outlined in the Pintrich framework for self-regulation, but with the addition of an "Intention" phase that describes initial student processes in open learning environments. As shown in the Zimmerman model, we combine the Monitoring and Control phases into a single phase, as Pintrich et al. have not found much separation of these processes in practical settings.[35] The complete framework used in this study is described in Table II.

Goals for this study

The goal of this study is to highlights issues in SDL that should be considered by instructors who wish to design self-directed undergraduate learning experiences. To facilitate our students' growth in SDL, we must strive to understand not only the outcomes and attitudes associated with SDL, but also the *causes* of student responses, and the individual cognitive, motivational, and behavioral *processes* that students employ throughout SDL experiences. In this work, we present preliminary results of a study designed to provide some initial insights into these issues. Through the lens of the theoretical framework for SDL, we examine student definitions of self-directed learning, and student descriptions of effective and challenging aspects of self-directed learning. The framework is used as a tool to identify key factors that contribute to students' SDL experiences, and as a mechanism for highlighting issues that bear consideration in the design, implementation, or evaluation of courses and curricula. The study was conducted at Franklin W. Olin College of Engineering (Olin College), which provides a particularly interesting environment in which to explore these questions, both because the curriculum places a heavy emphasis on self-directed experiences, and because the college has a nominally gender-balanced population.

Table II. Framework for self-directed learning based on Zimmerman and Pintrich models for self-regulated learning.[19,35]

	Phases of self-direction			
Areas for self-direction	**Intention**	**Planning, forethought**	**Monitoring, control**	**Reflection, reaction**
Cognition	Need recognition Opportunity assessment Choice of topic Choice to engage Openness to experience	Task analysis Goal-setting Activation of prior knowledge Activation of metacognitive knowledge Selection of strategies, resources, evaluations	Metacognitive awareness Self-recording Self-observation Judgments of learning Adaptation of cognitions and strategies	Knowledge of understanding and outcomes Self-evaluations of performance and outcomes
Motivation	Self-actualizing tendency Desire for growth Positive self view Perceptions of choice, ownership, control Intrinsic goal framing	Goal orientations and internalization Outcome expectations Self-efficacy Self-regulatory efficacy Perceptions of task difficulty, value Task interest	Awareness of self-efficacy, values, attributions, interests, anxieties Positive self-talk Anxiety control Self-rewards Adjustment of processes based on changing motivations	Efforts to enhance motivation Attribution of achievement to motivations Affective responses Ownership, connection to outcomes
Behavior	Positioning in learning environment Willingness to initiate and maintain learning schedule Allocation of learning time	Time, effort planning to attain goals Deadlines setting Self-assessment planning	Time and effort management and adjustment Acquisition and use of resources Adaptive help-seeking Persisting, effort focusing	Self-evaluation of efforts and actions Attribution of outcomes to behaviors and actions
Context	Choice of learning environment, social context Flexibility to learn in different settings Effects of setting on topic choice and desire to engage in learning	Perceptions of environmental features, assigned tasks, grading practices, classroom climate Establishing social/teaming interactions	Monitoring and modification of environment Elimination of distractions Negotiation of tasks and requirements Managing social interactions	Evaluation of task demands and environmental factors Change of environment

Methods

Subjects

Participants were undergraduate students from three engineering majors (engineering, mechanical engineering, and electrical and computer engineering) at a small, private, undergraduate engineering school. The sample of students included all classes, from first-year students to graduating seniors.

Measures

A survey instrument was administered to the entire student body in spring 2006. Students were informed that their participation was voluntary and that their responses would be held completely confidential. The survey included several parts: demographic information, quantitative survey items based on a 5-point Likert scale (1=strongly disagree to 5=strongly agree), and short answer survey items regarding students' self-directed learning experiences in their college courses.

Of the approximately 295 students at the college, 197 completed at least a portion of the survey, representing a 67% response rate. The gender (47% female, 53% male), age, and major distributions of the respondents closely matched those of the Olin College student body. In the quantitative portion of the survey, virtually all respondents reported that they had taken part in at least one SDL experience during their time at Olin College; most reported four or more such experiences. Of the 197 students who participated in the study, 159 students provided responses to the open-ended, short answer survey items used in the present study. Respondents to the short answer survey items included 77 females (48%) and 82 males (52%).

The open-ended, short answer portion of the survey included five items that prompted students to define self-directed learning and reflect on the effective and challenging aspects of SDL. The three survey items that were analyzed for this study are as follows:

1. *Provide a definition of self-directed learning*,
2. *List the features of self-directed learning that you think make it effective*, and
3. *List the features of self-directed learning that you think make it challenging*.

Analytic Strategies

Qualitative responses to the short answer survey items 2 and 3 were initially open coded for emergent themes. Sets of concepts from each question were grouped into categories and labeled with descriptive titles. Open coding continued until no new categories emerged from the raw data. Primary themes that emerged from the open coding of the "effective features of SDL" item were as follows: *motivation/interest/passion, choice/control/ownership, deep understanding, lifelong skill development, available resources, structure/goal-setting,* and *self-regulation of time and effort*. Primary themes from open coding of the "challenging features" item were: s*elf-regulation of time and effort, structure/goal-setting, motivation/interest/passion, choice/control/ownership, available resources, uncertainty in content learning*, and *teaming considerations*.

After open coding, we recognized that the emergent themes showed strong agreement with the processes described in self-regulated learning theories and models presented in the educational literature. As such, the detailed framework shown in Table II was prepared, and the raw data were once again evaluated with phase-area coding provided by the framework. Student responses to short answer survey items 1-3 were coded according to their identification or inference of particular self-directed learning phases and areas, e.g., Intention-Cognition, Planning-Motivation, Reflection-Cognition, etc. Many of the individual responses conceptually related to multiple phase-area codes. Several responses were sufficiently vague to make coding unfeasible, and a few responses noted concepts that did not correspond to the phase-area codes.

Results

Student responses to the short answer survey items 1-3 provided respective totals of 320, 359, and 326 relations to the phase-area codes within the detailed self-directed learning framework described in Table II. The distribution of these relations is summarized in Figure 1. Here each subplot indicates the number of student responses to each survey item for each phase-area coding. For example, examining the cognition-intention subplot, we see that a large number of survey item 1 responses ("definition of SDL") address this phase-area combination, while very few responses to survey item 3 ("challenging aspects of SDL") appear in this phase-area. In other words, student definitions of SDL often contain references to recognizing one's own learning needs, to choice of topic and to flexibility, but very few students identify these considerations when asked what makes SDL challenging.

Student definitions and comments tend to cluster in particular areas and in particular phases. As shown in Figure 1, student responses are heavily weighted toward the Cognition area, indicating that engineering students consider thought or reasoning processes to be an important component of SDL, and an attribute of SDL settings that may provide for both effective and challenging experiences. Examination of the subplots within the Cognition row shows that student responses regarding cognitions are focused on the "action" phases of planning-forethought (e.g., goal setting and selection of resources) and monitoring-control (adaption of learning plan, self-evaluation of processes), and to a lesser extent on the intention phase (e.g., learning needs assessment). Subplots within the Motivation row of Figure 1 show that student motivations are strongly emphasized at the *start* of SDL experiences (intention and planning phases). Few student definitions of SDL include motivations beyond these initial phases, and comments regarding motivational responses sharply decline once the monitoring and control phase begins. The subplots within the Behavior row indicate that students are aware of behavioral aspects of SDL (e.g., time and effort management), but that their behavioral considerations are limited to the action phases of SDL. Many more student remarks about behaviors reflect the challenging aspects than the effective aspects of SDL, and comments on behavioral challenges appear most frequently with regard to the monitoring and control phase. Subplots within the Context row of Figure 1 indicate that few students identify environmental factors as challenging or effective components of SDL, and few students include aspects of the classroom climate in their definitions of SDL.

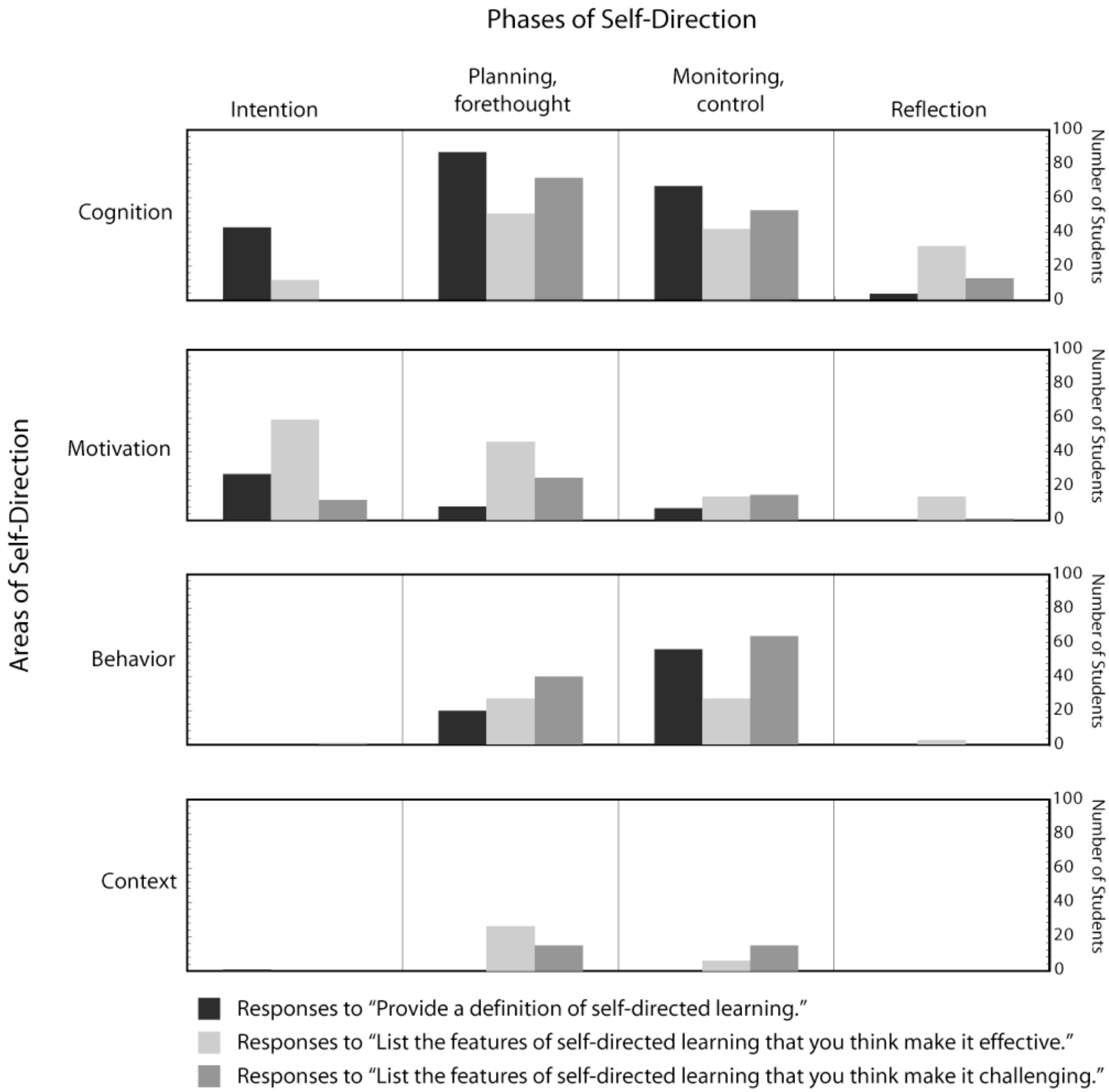

Figure 1. Results from coding of three short answer survey items according to the self-directed learning framework. N=159. Each subplot indicates the number of student responses coded for a particular phase and area of self-direction. For example, many student responses to all three questions dealt with cognitive aspects of the planning phase, while cognitive aspects of the reflection phase appeared primarily in answers to the second survey item (effective features of SDL).

Examination of the Reflection phase subplots (right column of Figure 1) reveals that a relatively small number of students identify reflection as a component of SDL. Nearly all of the comments about reflection lie in the cognition area, and most of these are related to students' positive views of their learning achievement.

In addition to the aggregated data shown in Figure 1, the coded responses were examined both by student year and by gender. Perhaps surprisingly, the distribution of responses is similar within all sub-populations. While some qualitative difference is evident between the responses of first year students and the responses of seniors (seniors' responses tend to reflect a greater range of experience and maturity), we did not observe any qualitative or quantitative difference between women's and men's responses. In this work we therefore have chosen to focus on the response of the population as a whole.

In the sections that follow, we summarize and discuss the kinds of comments that students made for each survey item as they map to each portion of the framework. We then discuss some of the implications of this study for the design of self-directed learning experiences. Finally, we describe our plans for future work.

Discussion

Student Definitions of SDL

Coding of the responses to survey item 1 (definition of SDL) reveals that students' definitions of SDL are concerned primarily with the **cognitive** aspects of learning that occur during the **planning and monitoring/control** phases (Figure 1). Many students are quick to recognize the importance of learning need recognition, goal setting, and selection of resources and strategies. Students often defined SDL as (to paraphrase) "a learning situation that has an end goal, methodology, and topic chosen by the participant." Comments on self-directed goal setting and strategic planning are not as widespread in responses from the first- and second-year students, however, and younger learners sometimes describe SDL as "learning in which you are provided with an end objective" or assume that "a simple set of guidelines will be given to you" by the instructor. One first-year student seemingly took the instructor influence to an extreme when he wrote that "self-directed learning is an education with individual goals intended to meet a professor's goals." This comment could reflect the student's well-developed processes for intrinsic goal framing or internalization of extrinsic motivations,[37] or it could reflect an under-developed conception of self-directed learning processes.

Students also cite the importance of monitoring and controlling of cognitions throughout the learning process, and "being flexible enough to understand when something on the proposed timeline isn't worth undertaking." Metacognitive awareness, or "understanding how you most effectively learn the material you're working on, and using that to your advantage," appears in some student definitions.

Many student comments that bridge the **cognitive** and **motivational** areas of SDL relate to content learning or "acquiring knowledge." Since the subjects in this investigation include students from all four years of the undergraduate programs, and with varied number and intensity of self-directed learning experiences, the views on content acquisition within SDL environments were diverse. Some student comments define SDL as starting when they are "presented with a topic or document or textbook" by the instructor, or when they "get an open topic/questions and you have to come up with an approach/answer by combining many types of knowledge resources." Other students apply a clear intrinsic motivational bent to the content acquisition aspects of self-direction. These students connect learning to their own passions and interests, and they describe SDL as "learning in which the motivation to learn a given piece of material is derived from your own motivations and not scripted by the professor," "learning for learning's sake," and "approaching subject matter…worth studying." Motivational aspects of SDL are clear when students discuss "the opportunity to explore something that they find personally exciting or significant," "a personal topic of interest," and motivating themselves to meet their own learning goals. One first-year student made his concern for motivation clear in his defining SDL as "learning that is not per a curriculum of THINGS YOU NEED TO KNOW, but rather is based upon you…deciding what is important for you to learn."

Behavioral aspects of SDL are also clearly identified in students' definitions, particularly in the planning and the monitoring/control phases of learning. Most comments regarding behaviors relate to setting a time or effort schedule, e.g., "making your own timeline," or adaptive/selective help seeking, i.e., when you "only go to a professor with questions." Some responses more generally noted the importance of solving problems or "going through academic material on one's own time."

Many student definitions of SDL noted cognitive or behavioral aspects of learning tied to resource identification and acquisition. Students commented on importance of instructor support in this process, but expectations regarding the levels of support varied. Some students believe that SDL involves "professors who act more as consultants than teachers" and who are "basically just a guide" for "defining the 'ballpark' of learning" or "double-checking connections made or concepts learned," while other students specify the need for a "general structure…directed by the professor" and resolve that "if a student determines they need a piece of information, and they ask their professor to provide it, the professor should answer or suggest a reasonable alternate resource." Reliance on instructor help in identifying and acquiring appropriate resources appears to be a key aspect of SDL, but perceptions of the ideal level of support varies dramatically from student to student.

Interestingly, definitions that included reference to **self-reflection** or cognitive, motivational, or behavioral reactions to the self-directed learning experience or context were practically nonexistent. One student included "evaluating knowledge of specified material" as a necessary aspect of learning, and a few students made mention of deliverables or grades, but no one commented on self-evaluations of performance, understanding of outcomes, affective responses, or attributions of learning outcomes to motivations, behaviors, or contextual factors. This failure to mention the critical reflection phase of self-directed learning may result from different factors. Since students completed the survey within the undergraduate college environment, they may have been considering experiences within their courses that were described by their instructors as "self-directed." As such, students may have interpreted the survey question as "Provide a definition of self-directed learning *in your Olin College courses*." With this interpretation, it would be reasonable for students to assume that they may control aspects of the learning planning and monitoring, but that evaluations of their development are the responsibility of their instructors. Alternatively, students may have neglected to include reflection in their definitions because reflection is seldom emphasized in undergraduate engineering courses. Engineering students are frequently pushed to their limits during the end-of-semester crunch time; "successful" completion of completing projects, reports, designs, and examinations often relegates thoughtful self-reflection to an academic afterthought. Clearly, the reflection phase of SDL provides an opportunity for improvement in our undergraduate courses and curricula.

Few students included comments regarding the **contextual** or environmental attributes of the learning environment in their definitions. A few students commented on "cooperation with teammates" and negotiation of evaluations. Similar to the self-reflection aspects of SDL, it could be that students in typical course settings simply do not have control over the classroom environment, or that they perceive little control over the social interactions, assigned tasks, grading schemes, and instructor style.

Effective Features of SDL

As observed in the student definitions of self-directed learning, **cognitive considerations** once again rose to the top as the most cited effective features of SDL. Many students believe that self-direction offers the opportunity for more effective learning. As one student noted, "I think you tend to dive deeper into a topic and retain what you learn significantly better. Material that I learn in a traditional lecture format generally doesn't last more than a semester after I learn it, whereas material that I learned the first time in a self-directed way will be easier to reengage with and harder to completely fade away." Students also appreciate "defining the scope of the learning" and "the freedom to redirect learning," and they note the importance of instructor support in initial direction setting and throughout the experience. Many students identify metacognitive gains in self-directed learning, such as the "ability to learn HOW to learn," and development of skills in self-observation and self-evaluation. Students explain that SDL "makes you think about how to get where you're going" and "forces you to really understand what you are reading or working with, instead of just spitting back equations or information that have not yet been internalized." As one student put it, "the best feature of self-directed learning is that it holds a mirror up to the student and shows him or her exactly what he or she can already do on his or her own, and what he or she should learn how to do before…the end of their schooling."

Students also identified **motivation** as an effective aspect of SDL. Based on student comments, self-directed learning can be fun – it "allows room for passion" and "engages one's creativity, which makes it very interesting and rewarding to do." Students' intrinsic motivations play a key role in determining engagement levels, particularly in the early phases of the learning experience. As one student put it, SDL is effective because of the "freedom to choose a subject you're passionate about." Choice in the learning topics and goals provides a sense of personal control, volition, and ownership that serves as a boon to intrinsic motivation. In the words of one student, "The sense of ownership and customization makes it exciting!" Freedom to explore an area of personal interest is a frequently cited motivational theme in the student responses.

Effective aspects of SDL in the **behavioral** realm include "learning at a pace that is comfortable," the "ability to modify and tweak around the schedule," "relying on your own time management." Students recognize that SDL teaches them to manage their time and efforts wisely, and they appreciate the opportunities to develop these self-regulatory abilities. Students also believe that "there is 'bonus learning' that happens, not in terms of the content in the chosen area, but learning about organization, logistics, communication, yourself…all of those soft skills that are really valuable."

In their discussion of the effective features of SDL, students often explicitly connected cognitive and metacognitive factors with motivational or behavioral development. Students report that self-directed learning "helps one learn the material better as well as more enjoyably," and allows students to see why they need to learn what they're learning." One senior noted, "it takes longer to learn a certain amount of information, but students learn it more deeply." Another commented that SDL "creates personal investment in knowledge gained, causing more productivity, higher retention, and deeper exploration." Of course, the engineering students' building of connections between intrinsic motivation and cognitions/behaviors, and their acknowledgement of the dramatic beneficial effects of contextualization, personalization and choice to their learning, are well supported by social-cognitive educational theory.[12,29,37,38]

While students did not strongly identify reflection in their responses to survey item 1 (definition of SDL), survey item 2 (effective aspects of SDL) prompted a significant number of students to describe the **reflection phase** of self-direction, especially with regard to their development of broad and transferable skills and attitudes. In the words of one junior, SDL "teaches a student how to think, NOT what to think – forces a student to take responsibility for her education to be successful, thus providing the student with life skills (versus physics knowledge, or ability to differentiate)." Students reflected on the benefits to their self-confidence, independence, and self-efficacy, e.g., "if nothing else, self-directed learning has taught me how to approach problems that seem impossible." In addition, many students expressed a sense of pride and satisfaction due to SDL, e.g., "there is always a much more profound and lasting sense of accomplishing something when you aren't just doing a problem set." The fact that students recognize reflection as an important and effective aspect of their experience, but do not call it out in the definition of SDL, is particularly interesting.

Contextual issues were cited by some students as effective aspects of SDL experiences. The choice of "surroundings that they find most conducive to learning," and the social interaction with peers were viewed as effective aspects of SDL. One student reported that "working in groups can also greatly improve learning, specifically when the skill levels are similar, so intelligent discussion occurs."

Somewhat surprisingly, several students reflected on the benefits of frustration and failure in their discussion of *effective* features of SDL. One student noted, "self-directed learning gives students the chance to fail. In that failure, more learning occurs than in any lecture," and another commented that with self-direction, "students must wrestle with complex issues on their own. While this may initially be frustrating and confusing, once a student has made the necessary connections, his or her understanding of the material is much stronger." These student comments identify a silver lining in the open-ended nature of certain SDL experiences, in contrast to the larger number of comments in the next section describing student anguish resulting from independence and uncertainty.

Challenging Features of SDL

The challenging aspects of SDL identified by undergraduate engineering students lie almost exclusively in two phases of learning: planning/forethought and monitoring/control. Student responses primarily addressed cognitive and behavioral challenges in SDL, although many students cited negative effects from motivational or contextual factors.

The reported **cognitive challenges** associated with SDL reflect students' difficulties with setting appropriate goals, selecting learning strategies, and identifying and acquiring resources. One senior, presumably with plenty of first-hand experience, responded that "self-directed learning is challenging because students' efforts are often poorly guided or focused, and frequently stray beyond the bounds of their goals." Students express concern that they "could potentially choose a topic out of their reach" or one that "doesn't challenge enough," and they worry about "not knowing enough to form a problem statement." "In the excitement, it's easy to get blown off course and spend a lot of time on something that's only tangentially related to your goal," another student commented.

In addition, students are challenged by the uncertainties associated with their learning or performance in SDL settings. Without feedback from instructors or other experts, students feel unsure about their selection of learning approaches, or uncertain about their competency in learning "the right thing." "If you don't have an answer key," one student notes, "it can be difficult and frustrating to learn from mistakes without guidance." Students express concerns and fears about learning things "the wrong way," "learning the 'wrong stuff'," "not learning the 'right stuff'," feeling totally on their own, "losing focus on the goal," "getting side-tracked," feeling lost, or "doing too much work because you aren't sure what you 'need' to know." Students sometimes are left wondering if they are learning everything they are "supposed to learn," or if their learning is "easily communicable to the professor…and whether it will be seen as academic or hokey." Regarding goal setting and effort planning, one student compared self-directed learning to problems sets:

> "…there's always this sense that I'm constantly falling behind. Problem sets are nice because at the end of the day I can say, 'The Professor wanted me to understand these problems. I did them, I understand. Check.' Often times, independent learning lacks this sense of achievement and satisfaction."

The need for instructor support of cognitive processes was listed by many students. In the words of one junior, "there comes a time when a student has banged his/her head against the wall long enough and it's time for the professor to step in a guide the learning at that point." A lack of an instructor "escape valve when things get difficult can make the experience frustrating," and "if you get lost, you're toast."

Cognitive planning and monitoring/control may negatively impact behavioral planning and monitoring/control when students must decide how much time or effort to exert in particular learning directions, or on particular learning strategies. As one student put it, "Without familiarity with the idea space, there is no way to schedule your time to be sure to hit the main points (or even to identify what the main points are)." Another student cautioned, "some fundamental knowledge of the discipline must precede the experience. If one is thrown into the deep end, there still needs to be a lifeguard on duty."

Students report significant problems with the **behavioral** aspects of self-direction, and time and effort planning and management are frequently cited as negative aspects of SDL. Students find the planning phase of SDL particularly challenging, as they have difficulty estimating the required time for tasks. They frequently choose projects of inappropriately large scope ("it's very easy to bite off more than you can chew"), and they do not always know when to pause or stop their efforts ("sometimes projects just spiral toward death, and that sucks"). In addition, students struggle with self-discipline; they comment that "…having few deliverables makes it easy to leave work until the last minute," and that self-directed activities "compete with more rigidly structured classes and obligations" and sometimes "sink to the bottom of the priority list." Student comments regarding negative behavioral aspects of SDL were often illustrative of students' honest affective responses. For example, one student stated, "I'm lazy. At heart, I want to read the internet and hang out with my friends. I have little self-control when it comes to enforcing my own deadlines." A senior responded, "we're given just enough rope to hang ourselves – particularly in terms of allocating a sufficient amount of time to learn the material." Regarding behavioral processes, several students commented on the challenges associated with transitioning from traditional learning to SDL, and students express frustration with unstructured SDL activities in which "the [learning] process is expected, but not taught." As described by a sophomore, "It is difficult to adjust from being spoon-fed the material in high school or some college courses to bearing most of the responsibility."

In some students' opinions, a lack of intrinsic **motivation** can also be a challenging aspect of SDL. Personal interest is required, and "everything falls apart" without it. Remaining passionately motivated is critical for some students, and when SDL environments fail to provide opportunities for personal connection or interest, they are left with "no internal drive to force [themselves] forward." One student illustrated his lack of intrinsic motivation in a particular setting: "someone just gave me something and told me to figure it out for myself, but I don't really care." Self-efficacy is highlighted in students recognizing that self-direction "requires a strong sense of assertiveness and much willpower" and that "self confidence issues make it a worse experience." "If a student is too timid and too afraid of failure, then they will not fail, and they won't learn as well." For many students, commitment, desire, focus, curiosity, and positive self-regard are requirements for SDL success.

Challenging **contextual factors** that were cited primarily focused on difficult teaming interactions. "Discouraging team dynamics," or teams comprising individuals with different interests, styles, goals, or backgrounds, were all cited as challenging features of some SDL environments. For at least one individual, self-directed learning was reported as a "lonely" experience. Other contextual factors that appeared in students' lists of SDL challenges include avoidance of various distractions, instructor-assigned grades, instructor-specified task requirements, and management of the student-instructor relationship.

As implied in the discussion of the negative cognitive and metacognitive aspects of SDL, some students find **reflection** and reaction particularly difficult, but very few provided specific comments regarding self-reflective processes. One student mentioned that, "real learning is difficult to realize without reflection and abstraction, which I find do NOT come naturally."

Implications of this Study

In this work, we have presented a framework for self-directed learning and we have used that framework to analyze student definitions of and responses to self-directed learning. We find that students define self-directed learning as focusing primarily on cognitive tasks associated with planning and monitoring the activity, and that most students have no difficulty identifying several positive and negative aspects of self-directed learning. Motivational considerations are frequently cited as significant positive aspects, while behavioral aspects (e.g., time management) are the most commonly noted negative aspects.

Examination of our results suggests a few key messages for instructors who wish to design self-directed learning experiences. First, **reflection tends to be undervalued** both by students and by instructors. The fact that students do not identify reflection in their definition of self-directed learning is particularly troubling, for it suggests that they may view reflection not as part of the learning process, but rather as a positive side effect that occasionally happens after-the-fact. It is, of course, heartening that students frequently refer to reflection as a positive aspect of SDL. However, most positive comments about reflection focus on learning process selections and learning performance (cognitive) and on time management behaviors. Students rarely refer to their development of attitudes or motivations or to their ability to interact with or shape their learning context, and they do not revisit their initial goals when the learning experience has ended. As instructors, it is important that we remember that learning happens not just in "doing" (planning, acting, monitoring, and controlling) but also in reflecting.

A second theme that emerges from student responses is the extent to which **motivation is key** for creating positive SDL experiences. In open coding student responses, this theme emerged again and again: as one student said, "I need to care." Similarly, motivation, particularly in the intention and planning phases, strongly emerges as an effective aspect of SDL. For instructors, the implication is clear: providing students with the opportunity to link learning to personal interests and goals, as well as the chance to make choices and be in control, leads to greater student investment and more positive student attitudes about self-directed learning. As instructors, we need to develop an understanding of the various ways in which we can enable student autonomy: what to learn (content), how to learn (process), why learn (motivations), and how well did learning occur (student self-assessment); so that the areas for student control are consistent and clear in the minds of both instructors and students.

Finally, there is clearly a need for us, as instructors, to develop better knowledge of the various aspects of self-directed learning, with particular emphasis on ways of **dealing with the challenges** that arise in classroom settings. While some students applaud the confidence-building experience of overcoming unforeseen challenges, a greater number report frustration at the possibility of failing to "learn the right stuff" or master unfamiliar information sources or research methods. Students entering college do not have all the necessary skills to master SDL without scaffolding and support from instructors; nor can they automatically understand how to balance and integrate their own goals, the instructor's goals, and disciplinary expectations when faced with an open-ended assignment. As instructors, we must design experiences to help students develop skills like time management, goal setting, and self-evaluation, so that students can become more autonomous as they progress.

Future Work

One way in which this work differs from most previous work in self-regulated learning is the inclusion of the intention phase in the framework to account for the open-ended nature of many self-directed learning experiences. While this work did not look in depth at the intention phase, there is clearly the need better to understand how and why students think and act when confronted with open-ended tasks or learning environments.

This work could also be extended by focusing more on individual responses, individual experiences, and the variations therein. By combining co-occurrence analysis of this data set with more in-depth interviews of individual students, it should be possible to generate "personas" who could be used to represent different student perspectives on self-directed learning, thereby providing a more complete picture of how different students think about SDL. Similarly, looking at changes in student attitudes about self-directed learning over the course of a single SDL experience might provide greater insight into specific questions of how the structure of an SDL experience influences student response.

Finally, much of the previous work in self-regulated learning has also focused on individual experiences as opposed to team experiences. Consequently, the idea that students might have to negotiate aspects of self-direction (e.g., project goal setting, strategy and resource selection, communication, merging different motivations) with teammates is not extensively discussed in the literature. Our experiences, and students' responses, indicate that such negotiation is critical in team-based SDL settings. For example, preliminary work has shown that that in some settings teams will tend to take a performance goal orientation, and that the team's orientation can lead to task divisions that directly conflict with an individual's desire to take a mastery goal orientation.[39] Clearly given the increasing use of team-based and project-oriented approaches in engineering education, it is important that we better understand how team dynamics interplay with self-direction.

References

1. American Society for Engineering Education Deans Council and Corporate Roundtable, "The Green Report: Engineering Education for a Changing World" (Washington, D.C.: ASEE, 1994).
2. National Research Council's Board on Engineering Education, "Engineering Education: Designing an Adaptive System" (Washington, D.C.: National Academy Press, 1995).
3. The Engineer of 2020: Visions of Engineering in the New Century. (National Academy Press (U.S.), Washington DC, 2004).
4. G. Clough, Educating the Engineer of 2020: Adapting Engineering Education to the New Century. (National Academy of Engineering, Washington, DC, 2005).
5. Peden, I.C., E.W. Ernst, and J.W. Prados, "Systemic Engineering Education Reform: An Action Agenda" (Washington, D.C.: National Science Foundation, 1995).
6. Criteria for Accrediting Engineering Programs, Accreditation Board for Engineering and Technology Engineering Accreditation Commission (2005). Available at http://www.abet.org/forms.shtml.
7. Rogers, C. R., Freedom to Learn: A View of What Education Might Become (Columbus, OH: Charles E. Merrill Publishing Company, 1969).

8. Candy, P., Self-Direction for Lifelong Learning: A Comprehensive Guide to Theory and Practice (San Francisco, Cal.: Jossey-Bass, 1991)
9. Hung, W., J. H. Bailey, D. H. Jonassen, “Exploring the Tensions of Problem-Based Learning: Insights from Research.” In D. S. Knowlton and D. C. Sharp (eds.), Problem-Based Learning in the Information Age, New Directions for Teaching and Learning, 95, 13-23 (San Francisco: Jossey-Bass, 2003).
10. MacKinnon, M. M. “CORE Elements of Student Motivation in Problem-Based Learning.” In M. Theall (ed.), Motivation from Within: Approaches for Encouraging Faculty and Students to Excel. New Directions for Teaching and Learning, 78, 49–58 (San Francisco: Jossey-Bass, 1999).
11. Skager, R., “Self-Directed Learning and Schooling: Identifying Pertinent Theories and Illustrative Research,” International Review of Education 25, 4 517-543 (1979).
12. Pintrich, P. R., and E. V. De Groot, “Motivational and Self-Regulated Learning Components of Classroom Academic Performance,” Journal of Educational Psychology 82 1 33-40 (1990).
13. Zimmerman, B. J., and A. Kitsantas, “Developmental phases in self-regulation: Shifting from process goals to outcome goals,” Journal of Educational Psychology 89 29-36 (1997).
14. Pintrich, P. R., “The role of goal orientation in self-regulated learning,” In M. Boekaerts, P. R. Pintrich, and M. Zeidner (Eds.), Handbook of Self-Regulation (San Diego, CA: Academic, 2000) 451-502.
15. Zimmerman, B. J., “Development of self-regulated learning: Which are the key subprocesses?” Contemporary Educational Psychology 16 307-313 (1986).
16. Knowles, M., Self-Directed Learning: A Guide for Learners and Teachers (Chicago: Association Press, Follett Publishing Company, 1975).
17. Zimmerman, B. J., Self-Regulated Learning and Academic Achievement: An Overview, Educational Psychologist 25 1 3-17 (1990).
18. Rogers, C. R., A Theory of Therapy, Personality, and Interpersonal Relationships, as Developed in the Client-Centered Framework. In S. Koch (ed.), Psychology: A Study of Science, Volume 3 (New York: McGraw-Hill, 1959).
19. Zimmerman, B. J., Attaining Self-Regulation: A Social Cognitive Perspective. In M. Boekaerts, P. R. Pintrich, and M. Zeidner (Eds.), Handbook of Self-Regulation (San Diego, CA: Academic, 2000) 13-39.
20. Zimmerman, B. J., A. Bandura, and M. Martinez-Pons, “Self-Motivation for Academic Attainment: The Role of Self-Efficacy Beliefs and Personal Goal Setting,” American Educational Research Journal 29 3 663-676 (1992).
21. Salomon, G. and D. N. Perkins, “Individual and Social Aspects of Learning,” Review of Research in Education 23 1-24 (1998).
22. Patrick, H., and M. J. Middleton, “Turning the Kaleidoscope: What We See When Self-Regulated Learning is Viewed With a Qualitative Lens,” Educational Psychologist 37 1 27-39 (2002).
23. Pilling-Cormick, J., “Transformative and Self-Directed Learning in Practice,” New Directions for Adult and Continuing Education 74 69-77 (1997).
24. Black, A. E., and E. L. Deci, “The Effects of Instructors’ Autonomy Support and Students’ Autonomous Motivation on Learning Organic Chemistry: A Self-Determination Theory Perspective,” Science Education 84 7 740-756 (2000).
25. Stefanou, C. R., K. C. Perencevich, M. DiCintio, and J. C. Turner, “Supporting Autonomy in the Classroom: Ways Teachers Encourage Student Decision Making and Ownership,” Educational Psychologist 39 2 97-110 (2004).
26. Assor, A., H. Kaplan, and G. Roth, “Choice is Good, but Relevance is Excellent: Autonomy-enhancing and Suppressing Teacher Behaviours Predicting Students’ Engagement in Schoolwork,” British Journal of Educational Psychology 72 261-278 (2002).
27. Evensen, D. H., J. D. Salisbury-Glennon, and J. Glenn, “A Qualitative Study of Six Medical Students in a Problem-Based Curriculum: Toward a Situated Model of Self-Regulation,” Journal of Educational Psychology 93 4 659-676 (2001).
28. Ryan, R. M., and E. L. Deci, “Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being,” American Psychologist 55 1 68-78 (2000).
29. Deci, E. L., and R. M. Ryan, “The “What” and “Why” of Goal Pursuits: Human Needs and the Self-Determination of Behavior,” Psychological Inquiry 11 4 227-268 (2000).
30. VanderStoep, S. W., P. R. Pintrich, and A. Fagerlin, “Disciplinary Differences in Self-Regulated Learning in College Students,” Contemporary Educational Psychology 21 345-362 (1996).
31. Noels, K. A., R. Clement, and L. G. Pelletier, “Perceptions of Teachers’ Communicative Style and Students’ Intrinsic and Extrinsic Motivation,” The Modern Language Journal 83 (i) 23-34 (1999).

32. Zimmerman, B. J., “Self-Regulation Involves More Than Metacognition: A Social Cognitive Perspective,” Educational Psychologist 30 4 217-221 (1995).
33. Garcia, T., and P. R. Pintrich, “The Effects of Autonomy on Motivation and Performance in the College Classroom,” Contemporary Educational Psychologist 21 4 477-486 (1996).
34. Stolk, J. and R. Martello, “Pedagogical Fusion: Integration, Student Direction, and Project-Based Learning in a Materials Science-History of Technology Course Block,” International Journal of Engineering Education 22 5 937-950 (2006).
35 Pintrich, P. R., “The Role of Goal Orientation in Self-Regulated Learning.” In M. Boekaerts, P. R. Pintrich, and M. Zeidner (Eds.), Handbook of Self-Regulation (San Diego, CA: Academic, 2000) 451-502.
36 Schunk, D. H., “Self-Regulated Learning: The Educational Legacy of Paul R. Pintrich,” Educational Psychologist 40 2 85-94 (2005).
37 Vansteenkiste, M., W. Lens, and E. L. Deci, “Intrinsic Versus Extrinsic Goal Contents in Self-Determination Theory: Another Look at the Quality of Academic Motivation,” Educational Psychologist 41 1 19-31 (2006).
38. Cordova, D. I., and M. R. Lepper, “Intrinsic Motivation and the Process of Learning: Beneficial Effects of Contextualization, Personalization, and Choice,” Journal of Educational Psychology 88 4 715-730 (1996).
39. Somerville M., Linder, B. and Eris, O., “Task Orientation: Are we doing students a disservice?” presented at Active Learning in Engineering Education, Toulouse, France (2007).