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Integrating Affective Engagement into Systems Engineering Education

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Integrating Affective Domain Development into Systems Engineering Education

Abstract

In this paper we address the challenges and importance of developing the students' affective engagement with the cognitive content offered in systems engineering education. Systems engineering is concerned with developing the most appropriate total system solution to address a need. Systems engineering methods used to find this solution require applying a systems perspective while making tradeoffs of the relative benefits of each set of possible approaches to a problem. However, the practical application of systems engineering is to seek a comprehensive design solution that satisfies a range of constraints and provides an adequate solution that "satisfices" the stakeholders. Applying the systems engineering method in order to gain the advantage of an optimal rather than adequate solution, demands that the systems engineer believes in the value of the methods, techniques, and perspectives of the systems engineering method, even at times where the method may seem indirect or counterintuitive to performing engineering work. Therefore, systems engineering education must engage the students in both the cognitive domain - developing ability to perform the techniques, and in the affective domain - transforming the student's belief to recognize the positive value of the systems engineering method. This paper discusses: 1) the current gap in addressing the affective domain in systems engineering education, 2) the importance of closing that gap to enable the effective implementation of systems engineering on the job, and 3) related issues and challenges. Following this discussion, the paper proposes a framework for assessing the development of the student's affective engagement in systems engineering methods.

Introduction

Systems engineering is the branch of engineering concerned with ensuring the development of the most apposite system to address a need. Theoretically, systems engineering begins with top-down evaluation of the need, leading to a deeper understanding of the attributes of a suitable solution, that in turn enables the design or selection of the best possible system solution. In practice, the top-down approach is counter-poised with situational exigencies concerning what is available, physically possible, permitted for use, or for which parties external to the development project have imposed constraints. As a result, the practical method of systems engineering is to seek a comprehensive design solution that satisfies a range of constraints and provides a good solution which satisfices the major stakeholders.

Systems engineering education stresses taking a holistic view of the situation to ensure that the system designed is the most appropriate throughout the system life cycle. Systems engineers typically have a background in a particular technology domain, providing the systems engineer a strong knowledge of certain technological possibilities in that domain, and much less knowledge of possibilities from other domains. As a result, systems engineers may pursue familiar choices over other more feasible solutions, particularly when in a situation of perceived pressure to deliver results. The combination of a bounded view of possibilities resulting from personal background and the tendency to pursue the familiar when under pressure leads to a bias not to pursue a truly holistic approach to projects. These inappropriate fundamental design decisions are locked in early, resulting in a less than optimal system design. Furthermore, in any working environment where the systems engineering approach is held in low esteem or is viewed as non-essential, it is up to the systems engineer to convince the team and leadership of the value proposition of systems engineering. To do this effectively, the systems engineer must believe in the value of systems engineering methods first, and then must be able to communicate that value proposition to the team and the leadership.

This paper explores educational issues associated with developing the affective aspect of the systems engineer to believe in the value of the systemic approach to engineering, and other affective domain characteristics associated with the development of “soft” or inter-personal skills necessary to engineering practice. The discussion is presented using the affective domain of educational outcomes in Bloom’s taxonomy combined with methods to establish teaching and learning tasks which will strengthen the student’s belief in the value of the methods about which they are learning.

Role of Affective Domain

The affective domain concerns the issues of feelings and values. In relation to systems engineering education the authors have, in discussion with various educators and practitioners, often encountered the view that the affective domain concerns how the individual addresses the interpersonal issues of conducting their professional work or the area of professional ethics, in which there is a clear association with the value system adhered to by the individual. The traditions, and in many cases legal and regulatory environment, of secular universities in secular states either constrain professional ethics education to being education about ethics, with intended outcomes such as recognition and articulation of what ethical issue is confronted in a particular situation, and teaching of the application of professional codes of ethics in various scenarios. The hope is that the student will choose to do the right thing because of their inherent value system and that the teaching about ethics will provide the intellectual capacity to recognize and reason about the issues presented in an ethical challenge. However, the values associated with the secular university in a secular state preclude the ethics class from aiming to change the student’s underlying foundation for their ethical framework. That is, the ethical foundation that the individual uses is assumed to be already established, and not to be transformed to a different framework, but rather to be accepted with the education concerning how to reason about applying that framework in situations presented by the practice of the discipline. This issue and its qualification by the secular tradition is expressed in ABET criterion (f) “an understanding of professional and ethical responsibility” [1].

There are two major approaches to understanding and organizing the competencies needed for engineering practice. These approaches are:

1. The competencies which accreditation authorities require for the accreditation of education programs; and
2. The competency frameworks developed by employers and others to guide employment and staff development policies and practices.

Engineering education in many countries is strongly linked to the accreditation process, in which university programs are examined by trained accreditors, appointed from outside the university by the accreditation authority, to ensure that the program is designed to and does actually achieve a range of criteria describing the achievements of graduates of the program by the time of graduation and for a defined post-graduation interval short enough to meaningfully relate to the education provided in the program. The ABET accreditation documentation describe these achievements as outcomes, for the time of graduation, and objectives, for the defined post-graduation interval. The ABET criteria (d), (f), (g), (h), (i) and (j), half of the full set (a) through (k), relate to the "soft" skills of teamwork, ethics, communication, contextual appreciation, self-development and contemporary knowledge and are easily, and superficially, associated with the affective domain [1]. However, it is clear that one could study about these areas as an external fact or learn about them in a manner that embeds them into one's approach to engineering. The former, learn about, outcome treats these areas as cognitive content to be learned. The latter, transformational outcome includes the affective characterization by the matter described.

Other signatories to the Washington Accord have accreditation criteria that address the same issues, even if expressed differently. These competencies are expressed for engineers in general, and therefore apply to systems engineers. The matters addressed in these criteria are easily recognized as associated with the affective domain since they relate to the values and personal practices of the students.

The second approach to competencies of systems engineers is the competency frameworks developed by employers or professional societies for the purpose of describing the range of competencies of systems engineers and levels of attainment in the various areas of competence. Several competency frameworks are available in the public domain [2-11]. At first glance the collective of these frameworks appears to emphasize a variety of particular areas of ability ranging from the technical skills of systems engineering through to the variety of soft skills. This impression arises because of the significant difference in the number of categories addressing technical and "soft" competencies. However, close investigation reveals that the apparent differences of balance result from the different needs in the organizations developing the framework and the degree of aggregation of competency into categories with broad headings [12]. The competency framework content about "soft" skills is an indicator of why many systems engineers understand an association of "soft" skills and affective domain. Research in the retail and engineering industries showed that the particular competencies emphasized by employers and by academics were different. Employers sought competency in teamwork, self-discipline, flexibility, language proficiency, work ethic, willingness to learn, positive attitude, dealing with conflict, leadership and decision making while academics emphasized work ethic, communication, customer service focus and ability to work as a team [13, 14]. It is notable that the competencies sought by employers concern the characterization of the person rather than things they know about or separate things they can do. A challenge in working with this conceptualization of the affective competencies is that, unlike the cognitive competencies, where there is a fairly clear view of what they mean in particular disciplines, there is much less consistency of description of what is sought or meant by terminology either within or between disciplines in universities [15].

The interpretation of the ABET criteria associated with the "softer" skills in the engineering education community has often resulted in the view that the affective domain is associated with such learning areas as communication, public policy, business and public administration, globalization, leadership, teamwork, attitudes, life-long learning, professionalism and ethical responsibility [16]. Haws reviewed multiple works on ethics education in engineering noting that one of the most common ethical problems in engineering is the omission of recognition of the ethical issues associated with a particular action [17]. He traced this to the thinking pattern of typical engineers being convergent, contrasting it to the divergent thinking required to recognize and engage with ethical issues. He further commented on the practice of engineering ethics education to, in many cases, approach the issue of ethics through the codes of professional ethics developed by engineering societies, saying that since those codes of ethics were written by engineers they contain the same blind points and that education based on them does not enable students to escape the thought constraints typical of engineers. Haws asserts that the success of teaching ethics to engineers depends on enabling the students to "cherish" their ethical responsibilities. The idea of cherishing the ethical responsibilities is an example of something very important in our argument. The goal of teaching ethics should not be that students will know about ethics, or be able to recognize the ethical issues in a range of taught cases, but rather that they will be transformed so that they naturally include consideration of ethical matters as part of their approach to professional work.

A second idea, which is prevalent among educators is that, the affective domain is important in education as a motivator of students to become excited by their learning of the cognitive content of their course. This perspective manifests in a variety of forms. Students may lack motivation to study because the presentation of ideas is dull and boring, even though the ideas themselves, when genuinely appreciated, may be profoundly exciting, because the manner of presentation or the communication of value of the study does not engage the affect [18, 19]. This issue arises because educators spend much effort investigating how students learn in the cognitive domain but little in considering how to achieve affective engagement [20, 21]. The problem of generational change in the expectation of students with respect to the manner in which they are taught and learn has been seen with the transition from Baby Boom to Generation X cohorts, where the latter want to be engaged by the medium of presentation, or even entertained, while they learn [22]. The issue of student motivation for learning has long been recognized as important in influencing the kind of learning that they students achieve. Students with a strong interest in a subject have an intrinsic motivation, which enables them to learn more deeply than those motivated extrinsically by a desire for a result. The use of the affective domain to engage the student through forming a deeper intrinsic motivation for learning is seen as desirable as a means to improve student results [23-25].

This paper develops a third aspect of affective domain learning, which is less obvious. The problem which our work aims to address is that of an engineer inappropriately jumping to conclusions about available design solutions too early in the system development process, as was mentioned above. The usual pattern in systems engineering education is to provide instruction related to the facts of, and methods to perform, systemic approaches to engineering. This content orientation concentrates on developing student knowledge about the technical content of systems engineering. Cognitive content is relatively easy to communicate in curriculum descriptions, to teach and to observe learning of in an 'objective' way. Concentration on the cognitive content as a body of knowledge separated from the practitioner also fits the notion of the content of education being free of encumbrance by the personal or other values of the people who know the facts. The people in the educational context include the students and the instructor. In turn, this view follows from the conceptualization of the secular university being concerned with the objectively knowable facts about the world and their application to achieving more complex constructs of knowledge of practical application, but not applying a gloss of any particular value system. It is expected that the facts can be taught and learned without any expectation of transforming the personality or values of the learners.

The effect is that the educated systems engineer has learned a set of methods and approaches for performing engineering work with the emphasis on analysis and design at the level of systems, in contrast to technological details which are the focus of most engineering analysis. Such a systems engineer is qualified in the technical competencies required to practice systems engineering. However, the education program may not have made a deliberate attempt to transform the learner's perception of and values about engineering to become fundamentally concerned with systemic approaches to engineering. The foundation for competency, which is absent, is that the learner does not become transformed by a deep-seated personal characterization of giving a high value to the systemic approach to engineering. In practice many systems engineers do have a high personal valuation of the systemic approach because of prior experience, which prompted their interest in studying systems engineering, but not all students have had such a background. It is desirable for all graduates in systems engineering to have a high enough valuation of applying the systemic approach to their engineering work that they will naturally, routinely and intuitively take a systemic approach rather than a technology centric approach or an approach driven by a rushed perception of the problem.

Shephard makes two observations related to this aspect of learning:

1. That educators often emphasize what students learn, a cognitive outcome, rather than what students learn to value, an affective outcome [21, 26, 27].
2. That the affective learning observations are often regarded as only being observable through long-term evidence and not amenable to assessment during the program of study [28].

This idea of the place and nature of the affective domain in education programs has a long history. Schmidt [29] refers to the idea in the mid 1970's but only as an author making use an existing idea. In addition, this perspective, that affective domain development in relation to the cognitive material which is learned, that we are pursuing in systems engineering is a perspective which has a long tradition in both theological education and military academies, where the objective is to develop people who *will* behave rightly, not just people who *know how to* behave rightly. Research about education aimed to produce affective domain outcomes is unusual [30]. In part, this neglect arises from the unclear definition of affective constructs and the underdeveloped assessment practices related to the affective domain, including scale construction [30]. Clearly the concept of focusing on developing students so that they will behave rightly is very different than teaching them about topics which pertain to knowledge about what constitutes right behaviour.

To avoid jumping to conclusions about the appropriate way forward in a project under both normal conditions, where there may be a temptation to assume one knows the right approach, or under challenging conditions, where it may appear counter-intuitive to perform systemic evaluation in order to accelerate project completion, it is necessary for the systems engineer to highly value and be characterized by the systemic approach to engineering work. To achieve this characterization in the graduate, the cognitive development is necessary so that students develop the necessary technical skills to perform the tasks effectively, but it is also necessary to develop the student's perception of the value of these skills so that their approach to work will be characterized by the exercise of these technical skills.

That is, the kind of development needed is that the student come to a position in which they believe in the value of the systems engineering approach to system development activities to an extent that they can overcome other driving forces, whether schedule pressure to appear to be delivering progress to simple human nature preference to stick to what is known, and implement systems engineering as intended. The development of belief in the value of the systemic methods can be achieved through purposeful design of the teaching content and assessment activities to achieve affective development in parallel with cognitive development.

Our view of the place of the affective domain in systems engineering education is consistent with Rovai *et al*'s quotation of Kearney that affective learning is "an increasing internalization of positive attitudes toward the content or subject matter" [31]. In turn, this observation shows that affective domain learning is concerned with attitudes and behaviours rather than cognitive development. The last sentence is important in the context of the earlier views of the affective domain in education, where it appears that some authors may be interpreting affective learning as learning about "affective topics", which is essentially a cognitive engagement with the subject matter of a topic characterized as "affective". Our emphasis is that affective learning results in transformation of the student to become characterized by valuation of the cognitive subject matter that the student learned through the program.

In summary it can be said that in the cognitive domain, systems engineers know how to do specific systems engineering tasks and that those tasks implement the tangible aspects of systems thinking, while in the affective domain they are characterized to do those specific tasks by embedding systems thinking because they personally value the benefit that those systems engineering tasks and systems thinking perspectives provide in addressing matters. The affective domain is not only associated with teamwork and leadership of projects, but also has a more subtle manifestation, so that the systems engineer naturally chooses to address matters in a whole system context and personally values making judgments about what is good or desirable to perform their work at a system level [32]. However, taking a systems thinking approach to the matter at hand appears to take additional time and effort and, therefore, is in tension with the pressure that usually exists to show tangible progress towards a solution to a need at a rate proportionate with the elapse of time spent or, other resources consumed, in the conduct of the engineering work.

Development of Affective Domain Characteristics

Bloom's taxonomy of educational outcomes was developed to provide a scientific foundation for curriculum design [33, 34] by setting the level of student attainment of learning outcomes in terms of the kind of learning achievement made by students. Bloom's taxonomy divides the learning space into the cognitive, affective and psychomotor domains. The original team developed only the cognitive and affective domains as hierarchies of learning achievement types. The cognitive domain addresses the development of intellectual abilities and skills related to knowledge of content and various abilities to use that knowledge. The affective domain deals with emotions, feelings and values. Many engineering educators regard the cognitive domain as concerning the knowledge of the technology of the particular engineering discipline and the affective domain as concerned with the so-called "soft skills" required for the practice of engineering in most workplace settings. The psychomotor domain was not developed by the original team. A number of attempts have been made to describe the psychomotor domain, with most pertaining to elementary development of psychomotor skills relevant to the early stages of education at the kindergarten and primary school level. There has been relatively little work focused on the articulation of psychomotor development relevant for professional, and engineering in particular, purposes. A discussion of both these aspects of development of the psychomotor domain is provided in Ferris [35].

We use the description of Bloom's taxonomy in both the cognitive and affective domains [33, 34] provided in the *Graduate Reference Curriculum for Systems Engineering*, GRCSE, [36] as a tool to enable discussion of student achievements that would constitute evidence of achievement of particular levels in the affective domain. Bloom's taxonomy is used in GRCSE to communicate the levels of achievement expected in the cognitive domain for each of the topic areas listed and explained in the Systems Engineering Body of Knowledge (see sebokwiki.org) product of the BKCASE project. In Appendix C of GRCSE the rationale for use of Bloom's taxonomy is explained. In addition Appendix C describes the affective domain of Bloom's taxonomy and provides examples of assessment tasks that would both challenge students to develop in their affective relation to topic areas and also provide assessment of this development.

In the preceding paragraph we used the expression "levels of achievement". Bloom's taxonomy was developed when behaviourist psychology was dominant, with the result that the view of learning development in it is hierarchical, and the intended outcome of education is that students are able to perform particular actions that are evidence of particular levels of learning achievement [37, 38]. The decline of behaviourist psychology has led to criticism of Bloom's taxonomy but the action perspective is well aligned with education in pragmatic disciplines such as engineering [39] but Bloom's taxonomy itself has remained as a common tool for describing educational objectives and for enabling description of the kinds of competency, or capacity for performance, that are both the objective and result of educational activity. We choose to use Bloom's taxonomy recognising the challenges to it that have been made by later theorists because in a pragmatic field of activity, such as engineering, the purpose of education is to develop people who are able to perform action and reliably make reasoned judgements about what should be done. This is usefully described, simply, by using a hierarchical structure. The levels in the hierarchical structure represents different types of thinking in relation to the subject matter. At the lowest level, for example, there is mere knowledge of the content without demonstration of ability to do anything much with the knowledge. At the higher levels are abilities to apply knowledge or to synthesize and evaluate new knowledge in the field. We recognize that the hierarchical structure presents these steps as sequential but that practically an individual may experience a spiral of knowledge development as they develop higher level achievement in some matters and later need to start learning in another area at a low level.

The descriptors of the knowledge developed at the various levels in Bloom's taxonomy, that is: knowledge, comprehension, application, analysis, synthesis and evaluation, in the cognitive domain and in the affective domain: receiving, responding, valuing, organization, characterization, build on each other but actually refer to different kinds of knowledge. The difference between the levels of attainment is not that a higher level indicates more knowledge but rather a higher level indicates having learned to think in a new way and therefore to be able to do a different kind of interaction with the field. Therefore the goal of education is to lead the student into new to them, elevated levels of thinking which enable different kind of action to be done. We also note that higher level achievement in the cognitive domain is associated with terms such as application, analysis, synthesis and evaluation. In Bloom's taxonomy these terms pertain to a range of abilities to apply existing knowledge and to synthesize new knowledge. In engineering these terms are often misunderstood to refer to the abilities to perform analysis and design of things using particular knowledge learned. The engineering professional activities of analysis and design pertain to the application of knowledge, using Bloom's terminology, to perform tasks, and the Bloom classifications of synthesis and evaluation refer to the creation of new knowledge, that is the doing of research.

As a generalization assignments in systems engineering courses are usually focused on the cognitive aspect of developing a systemic approach to engineering. To be more concrete, students are assessed on the cognitive dimension of their learning. This assessment is the means by which the student demonstrates development of the technical ability to perform systems engineering tasks. Our contention in support of development of the affective domain is that students need be challenged to think about and to transform their valuation of the methods of systems engineering so that they regard those methods as the natural and appropriate method to approach engineering work. An example of a cognitive assignment about systems engineering content may be a study of return on investment in systems engineering work. But this would only develop knowledge about the value of systems engineering but would not, in itself, necessarily lead the student to personally value systems engineering more deeply. What is needed is learning through experiences in which the student develops a clear sense of the benefit of systems engineering methods that causes them to perceive the methods to be compellingly valuable so that they then approach work using the methods.

For example, it is important to investigate students' systems thinking, an essential concept needed by systems engineers to do systems engineering work. Systems thinking must be developed in the affective domain in order that the depth of that learning can be understood and assessed. Based on the four levels of thinking model [40], systems thinking can be described by four distinct but closely related levels: events or symptoms; patterns of behaviors; systemic structures; and mental models [40, 41]. Events or symptoms are the most visible yet shallowest level of reality, and mental models reflect the deepest and most profound assumptions, norms, and motivations [41].

The first level, events and symptoms, although representing only the 'tip of the iceberg', are the level at which most decisions and interventions occur [41]. This is because events or symptoms are the most visible part of day-to-day reality, which often seems to require immediate attention and action [41]. The second level of thinking is patterns, where a larger set of events, or data points, are linked to create a 'story' [41]. The next level of thinking is systemic structures, which reveal how the patterns and components of the system as a whole relate to, and affect, each other [41]. This represents a much deeper level of thinking that can show how the interplay of different factors brings about the outcomes we observe [40]. In addition, the deepest level of thinking, the mental models, hardly ever comes to the surface. However, the mental models of individuals and organizations influence why things work the way they do [40]. Mental models reflect the beliefs, values and assumptions that people personally hold, and they underlie the reasons for doing things the way they do, and, in the context of a community, result in the community having a particular culture [40]. These mental models represent the affective domain of educational taxonomy.

In Table 1 we provide a generic development of the affective domain that relates the levels, sub-levels, competencies and outcome descriptors following the development of these ideas in Bloom's taxonomy. In this table, we also provide our development of specificity for systems engineering by presenting specific systems engineering relevant competencies, outcomes and potential assessment tools.

Current and Future Research

Our current study focuses on developing systems thinking in affective domain of undergraduate systems engineering students. Systems thinking is regarded as one of the important concepts which differentiate systems engineering from others engineering discipline. To measure student's development of the systems thinking construct in the affective domain, the self-reported survey of systems thinking was conducted at the beginning and end of a systems engineering course. Students were asked to complete the instrument shortly after the start of a course and again near the end of the course.

Table 1. Explanation of Bloom's taxonomy of affective domain levels, associated general competencies, and specific systems engineering relevant outcomes and potential assessment tools [36], [42] (Used with permission of Stevens Institute of Technology)

Level	**Sub-level**	**Competency**	**Example competencies**	**Outcome descriptors**	**Possible assessment tasks**
Receiving	Awareness Willing to receive Controlled or selected attention	The learner is aware of stimuli and is willing to attend to them. The learner may be able to control attention to the stimuli.	The student accepts that customer or user perception of the quality of a system is the fundamental determinant of system quality. The student accepts that customers do not always fully describe what they want or need, and that there is a difference between what customers say they want and what they actually need. The student is able to describe the value of the SE approach to design.	Focuses on and is aware of aesthetics, focuses on human values, demonstrates alertness to desirable qualities, and shows careful attendance to input.	An assignment to explain how customer or user perception of the system governs recognition of quality of the system. An assignment to explain the challenges in eliciting needs and/or requirements in a case study project. An assignment for the student to describe the financial value of SE work in projects.
Responding	Acquiescence in responding Willingness to respond Satisfaction in response	The learner makes a conscious response to the stimuli related to the aesthetic or quality. At this level the learner expresses a strong interest in aesthetics.	The student learns how to ask questions to elicit the unstated desires of a stakeholder who is seeking a system development. The student is willing to try the SE approach on a small project.	Demonstrates willing compliance and obedience to regulation and rules, seeks broad-based information to act upon, and accepts responsibility and expresses pleasure for one's own situation.	An assignment to interview project stakeholders about the needs/requirements for the system under development. A project for which SE methods are demanded with use of a reflective journal to discuss the usefulness of the SE methods.
Valuing	Acceptance of a value Preference for a value Commitment	The learner recognizes worth in the subject matter.	The student believes it is important to provide system solutions that satisfy the range of stakeholder concerns in a manner that the stakeholders judge to be good. The student believes it is important to elicit nuanced description of what stakeholders desire of a system in order to provide rich knowledge that can be used in the system solution development. The student believes in the value of the application of SE principles	Shows continuing desire to achieve, assumes responsibility for, seeks to form a view on controversial matters, displays devotion to principles, and demonstrates faith in effectiveness of reason.	An assignment to show the value to a system developer's future business from the reputational effect of properly attending to stakeholder needs. An assignment in which the student analyses the impact on a case study project where there is evidence that needs/requirements elicitation were significantly inadequate in capturing the real stakeholder interests. A task to provide a defence of use of SE methods, based on the information available at the time, in

			in a project, even in the face of advocates for other methods. The student recognizes the value of advancing in the proficiency of SE competencies.		the early stages of a case study project which used some other method. A task analysing the SE competencies and levels of attainment that are required for particular SE roles within a large project.
Organization	Conceptualization of a value Organization of a value system	The learner is able to organize a number of values into a system of values and can determine the inter-relationships of the values.	The student is able to organize a coherent framework of beliefs and understandings to support use of a SE method in a project. The student has a coherent framework for how to discuss system development with stakeholders in a balanced manner.	Identifies characteristics of an aesthetic, forms value-based judgements, and weights alternative policies.	An assignment to propose and justify through explaining the expected benefits, the use of particular SE methods and processes for a particular project. A project with "external" (to the academic department) stakeholders where the student must justify the method used to perform the project in terms of the expected benefit to stakeholders.
Characterization	Generalized set Characterization	The learner acts consistently with the systems of attitudes and values they have developed. The values and views are integrated into a coherent worldview.	The student will routinely approach system development projects with a SE framework. The student will routinely evaluate the appropriate tailoring of SE processes to appropriately address the specific characteristics of each project. The student will appropriately weight the views of all stakeholders and seek to overcome conflicts between stakeholders using methods that are technically and socially appropriate.	Readiness to revise judgement in light of evidence, judges problems and issues on their merit (not recited positions), and develops a consistent philosophy of life.	A practical examination requiring the development of a system concept where there is a tempting solution, that is obvious given the student's background, designed to test what the student does under time pressure. A project task in which there is significant conflict between the stakeholders, and assessing a combination of the result delivered by the student and a reflective journal about the process of resolving the conflicts.

When developing this instrument we found that the interest inventory for assessing Capacity of Engineering Systems Thinking, (CEST), introduced by Frank [43] is concerned with the affective domain. However, Frank's instruments only covered parts of our proposed systems thinking concept which need to be applied when engaging with an engineering system. Therefore, we created a new instrument by adding other systems thinking matters to Frank's instrument. About 60% of the questions in the original 30 item questionnaire were adapted from Frank's CEST instrument, while the remaining questions are new inclusions.
This instrument was intended to be completed independently by adults aged 18 years of age and older. We judged it essential that the questionnaire be short, four sides of A4 paper, quick to complete, approximately 10-15 minutes, easy to follow, comprehensible, and containing questions with language suitable for the target group. All items were arranged for scoring on a seven point Likert scale, with responses: 'very untrue of me', 'untrue of me', 'somewhat untrue of me', 'neutral', 'somewhat true of me', 'true of me' and 'very true of me'.

The preliminary data enable us to study the psychometric properties and validate the instrument. The participants included in this preliminary data are 180 undergraduate engineering students who enrolled in a systems engineering course in four universities in four countries: Australia, Indonesia, Singapore and US.

The relevant psychometric properties of this instrument, including, reliability and validity have been examined. The Cronbach's alpha obtained in this study is 0.908 which indicates excellent internal consistency [40]. The content-related validity of this survey is supported by the fact that the items are based on Frank's interest inventory for assessing CEST [39] and extensive literature review of issues related to students' learning about systems thinking in the affective domain. Face validity, tested by a short post-questionnaire interview with 8 adults representative of the population to be sampled indicated that the questionnaire is quick to complete (<20 minutes), easy to follow and comprehensible. Some grammatical changes to the questionnaire were conducted after this process. Construct validity, which indicates the extent to which the tool measures a theoretical construct, is examined through the exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) approach. The former approach focuses on the acquisition of a factor structure accounting of the relationship within the observed data, while the latter intends to test the hypothesized factor model [41].

The exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) processes resulted in a 22 item multidimensional scale with five factors which is a valid and reliable tool to assess students' ST in the affective domain. The five factors or constructs measured are students' valuation towards interdisciplinary and SE process, students' valuation for teamwork, leadership and understanding the whole, students' valuation towards understanding systems structure, hierarchy & boundary, students' valuation for understanding relationship, and students' personal characteristics. Overall, the factor analytic results were supportive of the theoretical framework underlying the development of the scale. Questions presented in the scale are provided in Table 2.

This study suggests that this instrument is suitable for measurement of students' learning of systems thinking in the affective domain and supports the view that the scale may be useful for further use. However, because the instrument is newly developed, it is crucial that the researchers continue to test the psychometric properties.

Table 2. The questions presented in the affective assessment

Number	Question Text
1	I prefer to deal with the technical details the rather than systems aspects.
2	When I encounter a problem I like to use multiple viewpoints to understand and analyse it.
3	I think I am good at personal project skill and personal organization skills.
4	I prefer concentrating on my technical job rather than leading teams.
5	I enjoy using models, mind maps, rich pictures, causal loop diagrams or graphs to understand problems.
6	It is important to me to acquire knowledge in engineering fields other than my main field of study (e.g. Electrical/Mechanical/etc. Engineering.).
7	It is important for me to learn from the differences between the expected and actual outcomes of action and change my action to improve results.
8	I do not like to understand the whole system structure including the system entities, their relationships, the system hierarchy and boundary.
9	It is important for me to identify the benefit derived from the combination of elements and actions of the system.
10	When I work in a group project (assignment) I value the contributions that the other students contribute to completing the whole task.
11	When I contribute to a group project (assignment) I never have interest to look at the interconnections and mutual influences between the main tasks and the peripheral task and how my part interacts with and contributes to the whole task.
12	When I contribute to a group project (assignment) I like to be proactive rather than just accept what has been decided by others.
13	When I contribute to a group project (assignment) I work hard to maintain communication with others involved.
14	When I contribute to a group project (assignment) I prefer to let others choose the preferred alternative rather than to test the available alternative solutions and then recommend the best choice.
15	When I contribute to a group project (assignment) I think continuously about what can be improved rather than concentrating on my goal alone.
16	When I contribute to a group project (assignment) I enjoy reviewing the whole and giving feedback to my group.
17	I do not see dealing with trade-off considerations (an exchange of one thing in return for another) as part of my engineering role.
18	I believe that I will enjoy finding out and analysing the customer or market need for a system and 'translating' the needs into technical specifications for products or systems.
19	I am not interested in the activities of others who contribute other discipline of knowledge in system development projects.
20	I am not interested in knowing how the final product or system produced by a project will be supported and maintained.
21	I believe that I will not enjoy participating in strategic planning that decides future directions.
22	If I need to make any change in a part or process for which I am responsible I will check the engineering and non-engineering consequences of the change.

Conclusions and Recommendations

This paper proposes that a purposeful pedagogical approach that combines cognitive and affective development objectives is essential to the content being integrated by the learner into their daily activities. That is, traditionally, teaching has focused on the learning of content and methods of action rather than on the value of applying the lessons learned in building cognitive expertise, or the transformation of the student to become characterized by their elevated valuation of the material that they have learned. Yet, the true value of systems engineering education, in particular, is in the application of the systems engineering principles, concepts, and methods in real life scenarios, even under pressure - either to meet project timelines or due to the company culture - when one is likely to regress to less effective approaches. By complementing a focus on the cognitive aspect of competencies with the affective development of the student with respect to those competencies through the levels of the affective domain of Bloom's taxonomy: receiving, responding, valuing, organization, and characterization, the educator can enhance the potential for the learner to incorporate the targeted content into their personal value and belief system and consequently their normal practice.

This paper maps a space in which systems engineering education integrates the cognitive and affective domains into outcomes that drive specific planning for development through the education process. This paper has developed a solid articulation of the issue despite the challenge of several other interpretations of what may be meant by the affective domain in systems engineering education. Having now advanced this work to the stage of a clear expression of what we mean by the affective domain in association with the cognitive domain in the development of systems engineering competencies, we can identify some areas of additional research to develop this concept further.

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