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Lessons learned in first time accreditation of engineering programmes

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ABSTRACT: In response to pressures generated by explosive growth in high technology and semiconductor manufacturing industries in the State of Texas in the 1990s, Texas State University (Texas State) established a programme in manufacturing engineering in 2000. Subsequent pressures in the form of intense global competition and the emergence of new technological industries in the State such as nanotechnology and biotechnology resulted in Texas State adding two additional engineering programmes. These include industrial engineering in 2004 and electrical engineering in 2008. In course of time, these engineering programmes grew and prepared themselves for the ABET accreditation process. As a consequence of preparing for the first time accreditation of three new engineering programmes, the authors have learned several valuable lessons. This article presents advice to those seeking first time ABET (or other) engineering accreditation for programmes by reviewing the work of other successful first time accreditation efforts, and by analysing similar processes that were necessitated at Texas State in preparation for the accreditation. In particular, the article presents discussions on writing *sound* learning outcomes and on the important, but often difficult to assess *soft skills* in engineering education.

Keywords: Engineering programme accreditation, learning outcomes assessment, continuous improvement

INTRODUCTION

At Texas State University, a new degree in manufacturing engineering was offered beginning in Fall 2000 [1]. This degree was the outcome of developments in the economy of the State of Texas in the preceding two decades. By the mid 1990s, the cities of Austin, San Marcos and San Antonio had all become part of one high-technology industrial corridor that stretched along Interstate Highway 35. Several manufacturing companies such as Applied Materials, Samsung Semiconductors, Freescale, AMD, National Instruments, Dell Computers, Tokyo Electron Limited, etc, had opened new facilities along this central Texas corridor [2].

In an article entitled *1998 Next Century Economy: Sustaining the Austin Region's Economic Advantage in the 21st Century*, a report prepared for the Greater Austin Chamber of Commerce, the authors stated that central Texas in the 1990s had added more technology jobs than Silicon Valley, Boston's Route 128 or the Research Triangle in North Carolina [3]. However, simultaneously with these outstanding economic gains, there was a lack of availability of a skilled professional workforce in central Texas. Several studies had attested to a chronic and crippling shortage of manufacturing professionals in this geographic area [4][5]. Many industries were considering relocating elsewhere in the US or outside the country, if qualified technical professionals with the ability to design, monitor and control processes could not be found.

In response to these critical challenges, the Texas Higher Education Coordinating Board (THECB) decided to develop a new higher education plan in the late 1990s. This plan entitled *Closing the Gaps* was developed and approved by THECB in October 2000 [6]. This plan has been largely instrumental in guiding public institutions of higher education in Texas to develop their strategic directions since 2000. One of the four goals in the *Closing the Gaps* plan focuses on ensuring that by the year 2015, the State of Texas would add 500,000 more students.

Another goal focuses on increasing by 50% the number of degrees awarded in certain key areas, such as engineering and computer science by the year 2015. Therefore, being a public university, Texas State made a strategic decision to offer degrees in manufacturing engineering, industrial engineering and electrical engineering in the period 2000-2007, with the intention of addressing regional industrial imperatives. Several new engineering programmes have been developed elsewhere in Texas and the rest of the nation over the last decade owing to similar industrial imperatives. Some salient details of these degrees at Texas State are presented below.

THE DEGREES

The design of each degree was strongly motivated by the criteria laid down by ABET, studies conducted by professional organisations, such as the Society of Manufacturing Engineers (SME), the Institute of Industrial Engineers (IIE) and the Institute of Electrical and Electronics Engineers (IEEE); forecasts made by the Bureau of Labor Statistics and the Texas Workforce Commission; and by the mix of industrial distribution in Texas. Accordingly, the Manufacturing Engineering (MfgE) degree was created with specialisations in General Manufacturing (GM) and Semiconductor Manufacturing (ScM). In 2012, a third specialisation, Mechanical Systems (MS), was added. The Industrial Engineering (IE) degree was created with no specialisations; the degree has been designed with sufficient generality to permit students to pursue opportunities in the industrial or service sectors. The Electrical Engineering (EE) degree was initially created with specialisations in Micro and Nano Devices and Systems (MNDS) and Networks and Communication Systems (NCS). Approximately, three years after its inception, a third specialisation, Computer Engineering (CpE), was added.

PROGRAMME CRITERIA

In preparation for accreditation, each programme must be evaluated against a set of programme criteria established by ABET [7]. All engineering programmes must meet a set of eight general criteria. These include:

1. Criterion 1 Students;
2. Criterion 2 Programme Educational Objectives;
3. Criterion 3 Student Outcomes;
4. Criterion 4 Continuous Improvement;
5. Criterion 5 Curriculum;
6. Criterion 6 Faculty;
7. Criterion 7 Facilities;
8. Criterion 8 Institutional Support.

In addition, programme-specific criteria exist for many programmes. For most programmes, the majority of the efforts in addressing these criteria are spent with General Criteria 2, 3 and 4: Programme Educational Objectives, Student Outcomes, Continuous Improvement.

The Programme Educational Objectives (PEO) are broad statements that describe what graduates are expected to attain within a few years of graduation. PEOs are based on the needs of the programme’s constituencies. Student Outcomes (SO) describe what students are expected to know and be able to do by the time of graduation. These relate to the skills, knowledge and behaviours that students acquire as they progress through the programme. The programme must have documented SOs that prepares graduates to attain the PEOs. Both PEOs and SOs must be compatible with both the ABET criteria and the institutional mission statement(s).

For the three engineering programmes at Texas State, the relevant mission statements are the university-wide statement, the College of Science and Engineering (CoSE) statement, the Ingram School of Engineering statement and the mission statements for each individual programme. These can be located at www.engineering.txstate.edu/degrees-programs.html.

CURRICULUM

The three major components of a curriculum as considered by ABET are a minimum of 32 semester hours of mathematics and basic sciences, a minimum of 48 semester hours of engineering topics, and *...a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.* The outcomes and objectives assessment process would be facilitated if the PEOs and SOs are mapped to specific courses. Ultimately, assessment of course learning outcomes is accomplished in individual courses. This in turn leads to the assessment of PEOs and SOs as a consequence of the mapping. The Texas State core curriculum consists of a proscribed 48 hour block required of all students, which satisfies the general education component. The curriculum total for Manufacturing Engineering is 132 semester hours. Industrial Engineering totals 135 semester hours. Electrical Engineering totals 137 semester hours. These credit hour totals are somewhat larger than preferred levels for programmes in the state of Texas and work is underway to bring these hours down to the 120 mandated by the state.

CHALLENGES AND ADVICE FOR FIRST TIME ACCREDITATION

Because the Manufacturing Engineering degree was the first engineering programme established at Texas State, it was the first to seek accreditation. Preparation for initial accreditation of this programme required preparation of a great deal of *ground work* which could be utilised by the subsequent programmes. Several challenges were encountered in the first time accreditation process, which may not have been encountered in schools that have a long track history of successful accreditation. Some of these challenges include the following:

1. There is great anticipation on the part of all stakeholders in the successful first accreditation, which can place some stress on the process and/or people charged with the accreditation effort.
2. New programmes are generally not as well connected to previous infrastructure and an information database needed for the programme review process.
3. New programmes populated primarily with younger, less-experienced faculty may not have resident experts in the accreditation processes. Typically, early-career engineering faculty are experts in their engineering discipline specific knowledge, but may have little or no knowledge in education assessment methodologies that may prove to be vital to the success of the accreditation effort.

In order to facilitate the first time accreditation effort, the following advice is offered based on the authors' experience and a review of relevant literature. The authors have direct cumulative experience with first time accreditation of the aforesaid three engineering programmes at Texas State and with the first time accreditation of the Computer Engineering programmes at the University of Alabama in Tuscaloosa, AL and the University of South Alabama in Mobile, AL. The review includes first time accreditation efforts in Computer Science at the University of Central Oklahoma [8], Industrial Engineering at Texas A&M University, Commerce [9], Computer Science at Virginia State University [10], Computer Engineering and Systems at the University of Washington, Tacoma [11] and a general discussion on accreditation efforts in Biomedical Engineering [12].

The following elements of advice were common to the many studies in the review and the authors of this article. These include:

1. Start the preparation process early; typically 2-3 years ahead of the site visit. This is necessary to allow sufficient time for implementing and documenting all aspects of the continuous improvement process.
2. Form a small, but active ABET faculty team that would meet regularly on some periodic basis. However, ensure that all faculty members are kept informed of developments.
3. Request institutional data (such as enrolment statistics) early in the assessment cycle as the personnel involved may have multiple clients and requests, and need to query several databases.
4. Hire an ABET consultant to review your materials and processes and make a site visit. This would literally be a *mock site visit*.
5. The course outcomes, SOs, PEOs and the mission statements of the programme, the department, the college/school and the institution must all be seamlessly mapped onto one another in a hierarchical fashion.
6. Confirm that the curriculum meets at least the minimum course hour requirements.
7. Form an industrial advisory board (IAB) to provide constituent input and an alternative perspective on curricular matters.

The following advice was provided by one or more the reviewed work and/or the authors:

1. Make sure that all stakeholders input and stay actively involved in the process, including the preparation of the self-study document.
2. Have one or more of the ABET faculty team volunteer to serve as programme evaluators with ABET. This service to ABET also provides the faculty member with outstanding training in the accreditation process.
3. In keeping with the old adage *Well begun is half done*, be sure to prepare the self-study as if the accreditation depended on the document.
4. Submit the self-study to internal and external stakeholders well in advance of the due date of 1 July. Targeting as complete a draft of the self-study as possible by early March is appropriate as far as these stakeholders go.
5. Have a good grasp of the ABET terminology (e.g. PEOs versus SOs). It is the experience of one of the authors who has served as an ABET programme evaluator that a lack of understanding in the differences between PEOs and SOs can have a significant detrimental effect on the entire accreditation process.
6. While you may replace ABET terminology with your own preferences, staying with ABET's terminology obviates any misunderstanding.
7. Resist the tendency to collect data before developing the mission statement, PEOs, SOs, course outcomes and the assessment process.
8. Use multiple methods to assess as many of the objectives as possible. This process is called *triangulation* [13] and is an important feature of effective assessment. However, too much data may be meaningless.
9. Develop a long range plan to measure PEOs periodically (say, once every 2-3 years and not necessarily on annual basis).
10. Understand the differences between direct and indirect measurement and avoid reliance on only indirect measurement.
11. Be sure your assessment processes *close the loop* and lead to continuous improvement.
12. Ensure that your documentation provides the necessary evidence for items 9 and 11 above. For example documentation of minutes from an annual faculty retreat, where issues and actionable efforts in relation to item 11 above were discussed, would prove very beneficial to verifying the face validity of the process. Similarly, documentation showing how actionable items from such discussions were applied to a specific course or a curriculum as a whole would be beneficial for item 11.
13. Bear in mind that in any accreditation effort the *processes* are as important (if not more so) as the *product*.

ASSESSMENT OF PEOs AND SOs

At the heart of the ABET accreditation process is the implementation and assessment of the PEOs and SOs. It is critical to distinguish properly between PEOs and SOs.

The process of deploying PEOs and SOs into course level student learning outcomes and identifying appropriate assessment methods can be a daunting task. Engineering faculty are typically not versed in the process of writing outcomes that are measurable. However, leading researchers propose that student learning outcomes are observable and measureable manifestations of applied knowledge. Hence, it is important to develop well-written learning outcomes; outcomes that are *clearly defined*, *observable*, *measurable* and *valid*.

In framing the discussion on outcomes and their assessment, it is useful, at a broader level, to think in terms of what programmes want students to know, think or do when they have completed their degrees. These three abilities are referred to by Nichols as the *cognitive, attitudinal* and *behavioural* aspects of student outcomes [14]. These correspond to the cognitive, affective and psychomotor domains or taxonomies identified by educational psychologist, Benjamin Bloom. Cognitive outcomes (knowledge outcomes) are related to what students learn in general and to knowledge acquisition [15].

Attitudinal outcomes relate to student attitudes and their state of mind and values [16]. Student outcome (h), *The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context,* would be an example of attitudinal outcome. Behavioural or psychomotor outcomes (skills outcomes) can be defined as an individual's reaction to either an external or internal stimulus. The integration of the cognitive, attitudinal and behavioural aspects of outcomes provides a comprehensive approach to defining a specific learning outcome.

Within each taxonomy or domain, Bloom breaks down domains into levels of expertise that are listed in order of increasing complexity. For instance, the cognitive domain can be broken down into six distinct levels of expertise. These include: *knowledge, comprehension, application, analysis, synthesis* and *evaluation.* Krathwohl has revised Bloom's categories in the cognitive domain by including an additional level from the affective domain which is *valuation*. These seven levels from the cognitive and affective domains, and Nichols three categories may be combined to yield the following:

1. Knowledge and comprehension (cognitive).
2. Application, analysis, synthesis and evaluation (behavioural).
3. Valuation (attitudinal).

The foregoing discussion on taxonomies is very useful in that it provides the framework for classifying statements of what faculty staff expect or intend students to learn as a result of instruction [17]. In fact, Bloom believed that his taxonomy could serve as a:

- *common language about learning goals to facilitate communication across persons, subject matter, and grade levels;*
- *basis for determining for a particular course or curriculum the specific meaning of broad educational goals, such as those found in the currently prevalent national, state, and local standards;*
- *means for determining the congruence of educational objectives, activities, and assessments in a unit, course, or curriculum; and*
- *panorama of the range of educational possibilities against which the limited breadth and depth of any particular educational course or curriculum could be contrasted* [17].

The aforementioned domain and categories facilitate the process of writing student learning outcomes. In terms of generality, one may proceed with writing outcomes by associating an outcome with one of the broad categories of cognitive, behavioural or attitudinal domains. Next Bloom's taxonomy may be used to determine the level of expertise required based on the requirements posed by measurable aspects of the outcome. In particular regard to the Criterion 3 (a)-(k) student outcomes, the following references offer a wealth of information. These references include: McGourty et al [18], Felder and Brent [19] and Besterfield-Sacre et al [16]. In addition, Bannister [20], Lindholm [21] and Shoemaker [22] offer general advice in regard to writing student learning outcomes. The following are some highlights from these references:

- ABET intentionally left the Criterion 3 (a)-(k) outcomes somewhat unspecified or broad in scope. Individual programmes could use these as a base and add specificity as might be appropriate for the programme.
- This lack of specificity can lead to difficulties when faculty have to plan for curriculum design and classroom learning *vis-à-vis* the Criterion 3 (a)-(k).
- Toward this end, Besterfield-Scare and her colleagues have created a list of outcomes/attributes. In this process, for each of the Criterion 3 (a)-(k) outcomes, a set of outcome elements are defined. These elements are different

abilities that are implied by the outcome statement that would require different assessment measures. Associated with each outcome element are outcome attributes. Attributes are actions that explicitly demonstrate mastery of the specified abilities. The attributes are so cast as to render them to be suitable for easy incorporation into assessment instruments and protocols.

- The framework for organising the outcome/attribute lists is based on a combination of Nichols' cognitive, attitudinal and behavioural components in combination with Bloom's general taxonomy as described earlier.
- These lists provide educators who wish to develop specific learning outcomes for a course or programme with a *buffet* of attributes from which to choose. Educators are strongly advised to consult Besterfield-Sacre et al [16] before proceeding to develop plans for classroom learning and assessment.
- Lastly, in interests of facilitating assessment, it is important that statements of outcomes contain verbs that describe observable, measurable, achievable actions and specific levels of thinking. Verbs that represent actions that are difficult to measure, such as *appreciate*, *be familiar with*, *master*, *comprehend*, etc, should be avoided. Instead verbs, such as *list*, *describe*, *identify*, *select*, etc, should be used. Besterfield-Sacre and her colleagues refer to this aspect of writing outcomes as *characterising the outcomes*. Outcomes should also try to avoid using multiple verbs and concepts, thereby permitting cleaner assessment.

Felder and Brent specify 21 different assessment tools of which some are applicable at the programme level and others at the course level [19]. These researchers make recommendations on instructional methods that are suitable for achieving the Criterion 3 (a)-(k) outcomes. Felder and Brent [19] and Besterfield-Sacre et al [16] provide examples of applications of the foregoing recommendations on writing *sound* learning outcomes and the reader is encouraged to consult these references prior to writing outcomes.

THE 120 HOUR DEGREE AND THE ABET PROCESS

Many states in the US mandate that the total number of hours for graduation with an undergraduate degree (engineering included) not exceed 120 hours. This move has been the consequence of many factors, but largely is due to increasing costs associated with college education. Similar government mandates on engineering programmes may exist currently or be imposed in the future elsewhere in the world as well.

As one surveys the list of student outcomes to be satisfied, a temptation may be to create many new courses to cover the broad range of outcomes that are necessary. However, in context of any 120 hour rule or target, this option is not feasible. A more feasible option is to incorporate any outcomes that are not currently being met into existing courses. In fact, in the case of both those outcomes that are currently being met and those that are not, a desirable practice is to meet an outcome by its incorporation in several courses. Felder and Brent advise that the coverage of outcomes should be distributed throughout the programme, not only for appearance's sake, but to provide repeated practice and feedback in skills the students will need to meet the outcome performance target [23]. Therefore, rather than have an outcome associated with communication skills addressed solely in the senior design course, it would be desirable to have this outcome addressed in several courses that span from freshmen level to senior level. Outcomes associated at various levels also allow for hierarchical learning as noted by Bloom, i.e. gain basic knowledge first, and apply and synthesise later.

ASSESSMENT OF SOFT SKILLS

The term *soft skills* refers to programme outcomes associated with themes, such as ethics, diversity, team work, life-long learning, global perspectives and communication. Examples include student outcomes 3d, 3f, 3g, 3h, 3i and 3j. By contrast *hard skills* refer to programme outcomes associated with themes, such as applying the principles of mathematics, science, engineering and technology or, say, with ability to solve technical problems. Technical faculty are well conversant with and adept in assessment of hard skills. These skills are typically assessed in technical courses, such as those in thermodynamics, control systems and materials science. However, technical faculty often have difficulty in managing the assessment of soft skills [23][24]. It would be worthwhile to have faculty attend focused seminars and webinars that address instructional strategies and assessment of select soft skills.

Since the advent of ABET's Engineering Criteria 2000 (EC 2000) some work has been reported on the issue of assessment of soft skills. In this section, based on a survey of prior work and the authors' experiences, advice is offered for first time accreditation efforts in regard to the assessment of soft skills. In particular, there are two issues to consider. These are: 1) where may soft skills best be assessed; and 2) what is the best assessment method? A number of programmes have sought to provide coverage of soft skills, such as ethics, diversity and global perspectives outside of the technical coursework in courses drawn from the humanities and social sciences. While these courses may offer an excellent opportunity to expose students to these soft skills, they may not be the best venue for assessment for many reasons. First, there is the issue of efficiently effecting classroom assessment from faculty who are not from the programme in which the accreditation is occurring [25].

Courses in the humanities and social sciences tend to be large (perhaps from being a part of the general education regimen) and include a diverse student population (technical students may constitute a small fraction in this population).

Second, there is the consideration of the contextual application of the soft skill, i.e. being able to apply the soft skill in a technical problem-solving situation [26].

Research indicates that in order to avoid the problems cited earlier that technical courses in the curriculum should contribute to the teaching and assessment of soft skills [24-28], courses with titles such as Electrical Power and Controls, Fluid Flow and Heat Transfer and Fluid Mechanics have been used to assess soft skills. In the case of the aforementioned courses the soft skill was assessed by embedding an activity, such as researching a new topic in fluid mechanics, such as *Man-made Non-Newtonian Fluids* or *Non-Petroleum Based Lubricants* or by providing a case-study on a topic, such as *Greenhouse Gases and Global Warming* in a course on electrical power and controls. In the latter course, the students were required to provide written answers to questions that stemmed from the case study as well participate in a class discussion on the case-study. The fluid mechanics course dealt with the soft skill, life-long learning, while the electrical power and controls course dealt with knowledge of contemporary societal and global issues.

The second issue concerns itself with which of the two methods of assessment, direct or indirect, is best suited for assessing soft skills. Wear and his colleagues, recommend assessing soft skills using direct methods wherein the assessment is based on some activity that is embedded within the framework of a course and evaluated using student work, such as responses to questions on a test or homework or project, etc [11]. This is in contrast to indirect methods, which typically are based on student responses to survey type instruments. Most of the work reviewed in this article used the direct method. In keeping with an earlier recommendation that each objective/outcome is best assessed using multiple methods, the authors recommend using a mix of direct and indirect methods, biased somewhat toward direct methods, to assess soft skills.

As a case in point in assessing the soft skill life-long learning, Briedis had teams of students in a course on fluid flow and heat transfer conduct independent research that involved the technical analysis of a device or system [28]. The devices or systems selected by student teams had to have some relationship with fluid flow or heat transfer or both. Students were required to turn in a written report and make an oral presentation. Using well defined rubrics, the aforementioned student work was graded. Life-long learning was also assessed using other measures that included the following: assessment of the participation of students in professional and technical societies by a Web based survey, and an alumni survey, which probed alumni participation in continuing education and in professional societies.

Finally, there is the consideration of the following, which is an issue with which most technical academicians are ill at ease. This is issue of conducting a hard assessment of soft skills. An article by Felder and Brent provides many excellent recommendations on this issue [23]. The authors reduce the challenge in the hard assessment of soft skills to the evolution of a grading process that is reliable (meaning different evaluators would assign identical scores on assigned work) and fair (students are fully aware of the criteria involved in grading) and recommend grading checklists and rubrics as instruments that may facilitate this process.

One of the author’s direct experiences involves three different approaches for addressing *soft skills* for the first-time accreditation of electrical and/or computer engineering programmes at the University of South Alabama, the University of Alabama and Texas State University-San Marcos. At the University of South Alabama, the electrical and computer engineering programmes shared a 1-hour course, EE 301: Professionalism and Ethics in Electrical and Computer Engineering. The specified purpose of this course was to teach and assess the *soft skills* for all students in these programmes. The content and structure of this course were praised by the ABET visitors, but evidence of breadth of soft skill adoption across the curriculum was initially questioned. The addition of further assessment of the *soft skills* in the Capstone Design course sequence helped to address this concern.

At the University of Alabama, the first presentation and assessment of the soft skills were made in the first electrical engineering course, EE 125: Introduction to Electrical Engineering. This was followed by further assessments in the courses common to all sub-disciplines such as Circuits, Microprocessors and the Capstone Design sequence. Distributing *modules* on the soft skills across a number of common courses allowed the topics to be widely integrated and their importance emphasised in many places. At Texas State, the *soft skills* are addressed and assessed in a number of courses beginning with the first Circuits course and culminating with the Capstone Design sequence. This distributed approach serves to allow the skills to be integrated into the curriculum without significantly impacting the amount of time needed in any given course.

CONCLUSIONS

The authors' experiences in going through the first-time accreditation of the manufacturing engineering, industrial engineering and electrical engineering programmes helped them gain considerable understanding of the ABET accreditation process and usher in a *learning outcomes assessment culture* where one had not previously existed. While the authors had to work with ABET to resolve *issues* after the accreditation visits associated with the manufacturing and industrial engineering programmes, by the time the electrical engineering programme visit occurred, the authors had gained considerable in-house expertise with the assessment process. The visiting team complimented the institution on the self-study report, which was praised as a *model* report.

As noted earlier, the bulk of the accreditation effort was in regard to General Criterion 2: Programme Educational Objectives, General Criterion 3: Student Outcomes and General Criterion 4: Continuous Improvement. The importance of generating well defined and articulated PEOs and SOs that are in alignment with multiple mission statements can hardly be overemphasised. Incorporating appropriate assessment tools and the use of triangulation in assessment significantly facilitates the process.

Although technical skills are essential, particular attention must be paid to the assessment of soft skills. The assessment of soft skills in technical courses using direct methods is recommended. All in all, the authors' experience with the accreditation process was positive. At the successful conclusion of these long and arduous processes the authors feel they have, in the truest traditions of continuous improvement, moved the programmes forward.

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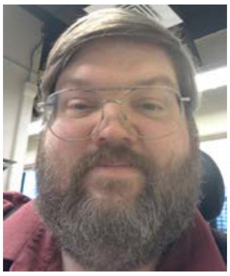

William Stapleton is a founding member of the Ingram School of Engineering faculty at Texas State University - San Marcos with a specialisation in electrical and computer engineering. He was heavily involved in the creation of the electrical engineering programme and was the architect of the computer engineering option within electrical engineering. At his previous positions, first at the University of South Alabama, then, at the University of Alabama, he was involved in the successful efforts to accredit computer engineering for the first time at both institutions. Dr Stapleton has a keen interest in achieving successful engineering pedagogy, especially in the computer engineering area. Dr Stapleton's personal areas of research interest include parallel and distributed computing, image processing, embedded computing and sensor networks.