

Using Rubrics to Assess the Development of CDIO Syllabus Personal and Professional Skills and Attributes at the 2.x.x Level*

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The Department of Aerospace Engineering at the United States Naval Academy (USNA) in Annapolis, USA, joined the CDIO Initiative (Conceive – Design – Implement – Operate) in July 2003. The US Naval Academy already emphasised many of the skills in the CDIO Syllabus, such as ethics, leadership, teamwork, systems thinking and communications, which are part of design-build projects, integral components of a CDIO programme. What was lacking was the overall framework for developing a curriculum that was consistent with the Department's goals and one that could be used to guide outcomes assessment. The CDIO Syllabus provided that framework. In this article, the authors describe the process of developing and implementing the CDIO Syllabus personal and professional skills and attributes (2.x.x).

INTRODUCTION

The CDIO (Conceive – Design – Implement – Operation) project learning assessment model is based on the principle that product and system lifecycle development and deployment are the context of engineering education. Its mission is to graduate engineers who are able to conceive, design, implement and operate complex, value-added engineering products and systems in modern team-based environments so as to appreciate engineering processes and contribute to the development of engineering products while working in engineering organisations.

As a result, the intended attributes of CDIO graduates include the following:

- Understanding disciplinary fundamentals;
- Understanding design and manufacturing;

- Possessing a multidisciplinary system perspective;
- Exhibiting good communication skills;
- Having high ethical standards [1].

Of course, each CDIO programme develops expected student learning outcomes that are consistent with the programme mission and are validated by programme stakeholders. Typically, programme outcomes include technical knowledge and reasoning, personal and professional skills and attributes, interpersonal skills such as teamwork and communication, and conceiving, designing, implementing and operating systems in the enterprise and societal context.

USNA'S ADOPTION OF CDIO

The Department of Aerospace Engineering at the United States Naval Academy (USNA) in Annapolis, USA, joined the CDIO Initiative in July 2003. The CDIO Initiative provides it with the framework and tools necessary to make and assess changes in the Department's programme. Before describing why and how CDIO was adapted to the programme, it is necessary to understand the mission of the United States Naval Academy, which is as follows:

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Develop midshipmen morally, mentally and physically and to imbue them with the highest ideals of duty, honor and loyalty in order to provide graduates who are dedicated to a career of naval service and have potential for future development in mind and character to assume the highest responsibilities of command, citizenship and government [2].

The mission of the Department of Aerospace Engineering must follow from the mission of the Naval Academy, while at the same time emphasising the role of the aerospace engineering major. The Departmental mission and vision are a direct result of its participation in the CDIO Initiative. The Department's mission is to: Provide the Navy and Marine Corps with engineering graduates who are capable of growing to fill engineering, management and leadership roles in the Navy, government and industry, maturing their fascination with air and space systems. The Departmental vision follows this mission: mission fulfilment requires a programme wherein midshipmen Conceive – Design – Implement – Operate complex mission-effective aerospace systems in a modern team-based environment.

The US Naval Academy already emphasises many of the skills in the CDIO Syllabus, such as ethics, leadership, teamwork, systems thinking and communications, which are part of design-build projects, integral components of a CDIO programme [3]. What was lacking was the overall framework for developing a curriculum consistent with Department's

goals and one that could be used to guide outcomes assessment. The CDIO Syllabus provided that framework. In this article, the authors describes the process of developing and implementing the CDIO Syllabus personal and professional skills and attributes (2.x.x).

A stakeholder survey was first completed in order to determine the level of understanding desired for each of the CDIO Syllabus topics. Following that, a benchmark survey was completed of the courses to identify where to introduce, teach and use each of the topics in the CDIO Syllabus. In the next step, the Department is evaluating student and programme performance in each of the topics. The focus in 2007 is particularly on personal and professional skills and attributes (2.x.x). In those courses where it has been identified that the 2.x.x topics be taught or used, each faculty member is asked to evaluate a student's performance on the topics by answering a set of questions pertaining to the 2.x.x topics. These questions are applied to course homework, projects, examinations and class participation.

ASSESSMENT USING RUBRICS

A student learning assessment model is used to guide CDIO practice (Figure 1). This model provides an approach to student learning assessment that is based on the CDIO standards and the local programme context. The model may be used at the course, programme or institutional level. It describes four elements of student learning assessment, specifically:

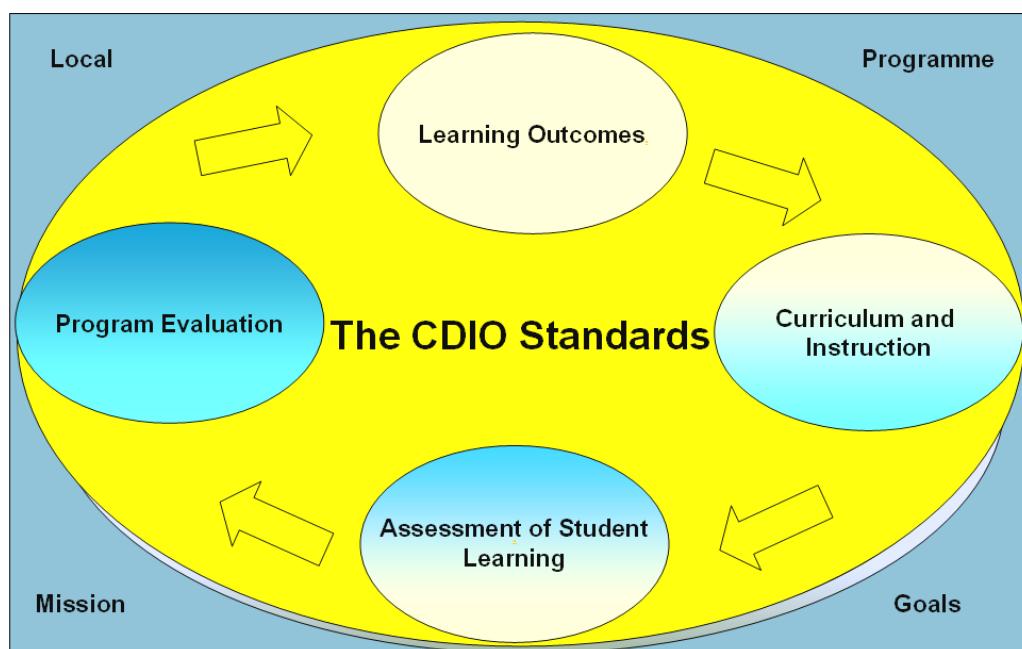


Figure 1: The CDIO student learning assessment model.

- Learning objectives;
- Curriculum and instruction;
- Assessment of student learning;
- Use of assessment results.

The model highlights the importance of aligning teaching, learning and assessment with the CDIO and local programme's intended learning outcomes, as well as the use of assessment results to improve the processes of teaching, learning and assessment.

Assessment requires faculty members to communicate explicit and public statements of learning outcomes and criteria of performance. By doing so, they refine their own understanding of the expected abilities, clarify for their colleagues the basis for their judgements, and enable students to understand what learning and level of performance are required [4].

A CDIO programme uses a variety of evaluation methods to determine whether or not students have acquired the knowledge, skills and values specified in the CDIO Syllabus. The methods available to gather and evaluate student learning include written tests, as well as rating scales (ie rubrics) for evaluating student performance in the form of journals of student reflections, portfolios of student work over time, capstone projects (eg design/build efforts), and oral presentations, in-class discussions and technical reports.

This year, the Department of Aerospace Engineering faculty members focused particularly on the personal and professional skills and attributes (2.x.x in the CDIO Syllabus). In the courses where the teaching or use of the 2.x.x topics had been identified, each faculty member was asked to evaluate a student's performance by answering a set of questions pertaining to the 2.x.x topics in the form of a scoring rubric. Figure 2 shows the criteria for assessment of each of the personal and professional skills and attributes included in the 2.1.x level in the Syllabus.

An example of a rubric developed and field-tested this year is presented in Table 1. This rubric was applied to individual presentations, posters, team presentations, technical reports, laboratory reports, in-class discussion and other artefacts of student performance. The seven syllabus topics with the highest scores from the stakeholder survey were selected and the faculty rated students using the same rating scale utilised in the stakeholder survey. Table 1 shows the data collected for a single course with 13 students. In this course, six of the skills were *used* and one of the skills were *taught*.

The rating scale used to generate the data is the

same rating scale that was used in the stakeholder survey. The scoring (1-5) is as follows:

1. To have experienced or been exposed to;
2. To be able to participate in and contribute to;
3. To be able to understand and explain;
4. To be skilled in the practice or implementation of;
5. To be able to lead or innovate in.

The specific CDIO Syllabus 2.x.x topics that were assessed are as follows:

- 2.1.1 Problem Identification and Formulation;
- 2.1.2 Modeling;
- 2.1.3 Estimation and Qualitative Analysis;
- 2.1.5 Solution and Recommendation;
- 2.4.2 Perseverance and Flexibility;
- 2.4.4 Critical Thinking;
- 2.5.1 Professional Ethics, Integrity, Responsibility Accountability.

2.1 ENGINEERING REASONING AND PROBLEM-SOLVING

2.1.1 Problem Identification and Formulation

Evaluate data and symptoms

Analyse assumptions and sources of bias

Demonstrate issue prioritisation in context of overall goals

Formulate a plan of attack (incorporating model, analytical and numerical solutions, qualitative analysis, experimentation and consideration of uncertainty)

2.1.2 Modelling

Identify assumptions to simplify complex systems and environment

Choose and *apply* conceptual and qualitative models

Choose and *apply* quantitative models and simulations

2.1.3 Estimation and Qualitative Analysis

Estimate orders of magnitude, bounds and trends

Apply tests for consistency and errors (limits, units, etc.)

Explain the generalisation of analytical solutions

2.1.4 Analysis with Uncertainty

Question incomplete and ambiguous information

Interpret probabilistic and statistical models of events and sequences

Interpret engineering cost-benefit and risk analysis

Discuss decision analysis

Identify margins and reserve

2.1.5 Solution and Recommendation

Select problem solutions from among candidates

Analyse essential results of solutions and test data

Analyse and *reconcile* discrepancies in results

Choose summary recommendations

Appraise possible improvements in the problem-solving process

Figure 2: Personal and professional skills and attributes.

Table 1: Assessment data for a single course and 13 students.

2.1.1	2.1.2	2.1.3	2.1.5	2.4.2	2.4.4	2.5.1
Use	Use	Use	Use	Use	Teach	Use
2	1	3	3	2	1	4
3	3	3	3	3	3	4
2	1	3	3	2	3	4
3	3	3	2	3	2	4
3	3	3	3	2	2	4
3	3	3	4	3	3	4
3	3	3	3	3	3	4
3	3	3	4	3	4	4
3	3	3	4	4	4	4
3	3	3	4	4	4	4
3	3	3	3	3	3	4
3	3	3	3	4	4	4
2	1	2	2	3	3	4

LESSONS LEARNED AND NEXT STEPS

Of all the syllabus topics, the personal and professional skills and attributes (2.x.x syllabus topics) appear to be the most difficult to measure and the most subjective. The task seemed overwhelming until it was decided to reduce the number of skills to be assessed. Table 1 presents the results from one course with 13 students. Based on the curriculum benchmark results, the only CDIO skill taught in this course was 2.4.4: Critical Thinking. The other CDIO skills used in this rubric were used in the course and observed by the instructor, but not necessarily taught in the course.

Ratings for the courses are shown in Table 2 and Figure 3. The data are the average values for each CDIO skill for each year group. The last line of the table and the last column for each skill in the figure show the goal for each skill. This goal is based on the input for the stakeholder's survey using the same rating scale.

The data shown in Table 2 and Figure 3 indicate improvements in all of the topics from the 2nd year to the 4th year. These data represent a snapshot of the programme at the end of the spring 2007 semester and is not longitudinal data. In other words, the students evaluated in the 2nd year are not the same students evaluated in the 3rd and 4th years, but rather the data represent where students were assessed in each of the year groups at that time.

Also, the data indicate that the Department is close to, or meeting, the objective in six of the seven skills. The skill where the assessment falls short of the desired level based from the stakeholder survey is 2.1.1: Problem Identification and Formulation. In order to improve students' problem-solving skills, a standard problem-solving handout has been introduced to students in their 2nd year and all faculty members are being encouraged to use the handout in subsequent courses in the programme.

Finally, a separate assessment tool indicates that students' critical thinking skills (CDIO Syllabus Topic 2.2.4) are not at the level desired. To improve their critical thinking skills, a Critical Thinking Workshop

Table 2: Assessment data for 2007.

Year	2.1.1	2.1.2	2.1.3	2.1.5	2.4.2	2.4.4	2.5.1
2 nd year	2.79	2.89	2.73	2.72	3.08	2.88	3.34
3 rd year	2.56	2.75	2.77	2.60	3.26	2.81	3.42
4 th year	3.23	3.35	3.32	3.39	3.40	3.35	3.52
Goal	4.1	3.2	3.6	3.6	3.3	3.6	3.7

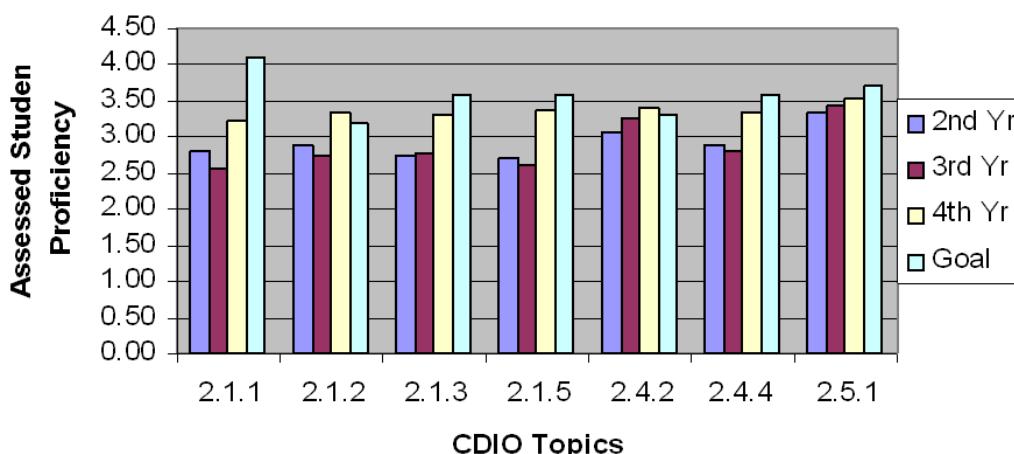


Figure 3: USNA assessment of CDIO 2.x.x topics.

was introduced for those students in their 2nd year. This workshop provides students and faculty members with a standard language for evaluating student work. Again, faculty members are encouraged to use this language in subsequent courses.

REFERENCES

1. CDIO Initiative, <http://www.cdio.org/index.html>
2. United States Naval Academy (2007), <http://www.usna.edu/welcome.htm>
3. Boden, D.G. and Gray, P.J., CDIO: its adoption and assessment at the US Naval Academy. *Proc. 5th Global Congress on Engng. Educ.*, New York, USA, 31-34 (2006).
4. Loacker, G., Cromwell, C. and O'Brien, K., *Assessment in Higher Education: to Serve the Learner*. In: Adelman, C., Assessment in American Higher Education. Washington, DC: US Department of Education, 47-62 (1986).

BIOGRAPHIES



Prof. Boden earned his PhD in aeronautical and astronautical engineering from the University of Illinois in 1986. His educational focus was on astronautics, particularly orbit determination and estimation. He served for 20 years in the United States Air Force and retired as a

Lt. Colonel in 1993. While on active duty in the Air Force, he taught in the Department of Astronautics at the United States Air Force Academy from 1980 to 1993.

Following retirement from the Air Force, he moved to the United States Naval Academy where he has been a member of the faculty since 1997. While a member of the Aerospace Engineering Department, he has served as the Director of Astronautics and the Department Chair. Dr Boden edited the book, *Cost-Effective Space Mission Operations*, and authored several chapters in books in the Space Technology

Series. Recently, he has authored several papers detailing the US Naval Academy's participation in the Conceive – Design – Implement – Operate (CDIO) project and he has conducted numerous CDIO workshops around the world.



Dr Gray earned his PhD in educational psychology from the University of Oregon and his Masters degree in curriculum theory from Cornell University. His areas of higher education expertise include student learning outcomes assessment; evaluation and research methodology; institutional effectiveness and quality assurance; course, curriculum and programme design, development and evaluation; and leadership and planned change.

From 1984 to 2002, he was the Associate Director of the Syracuse University Center for the Support of Teaching and Learning. He became the Director of Academic Assessment at the United States Naval Academy in August 2002, where he is responsible for developing and maintaining a broad programme of academic assessment.

Dr Gray has over 40 publications including the chapter Roots of Assessment: Tensions, Solutions, and Research Directions in *Building a Scholarship of Assessment* (Banta, editor, 2002) and Viewing Assessment as an Innovation: Leadership and the Change Process in *The Campus-Level Impact of Assessment: Progress, Problems, and Possibilities. New Directions in Higher Education* (number 100, winter 1997, co-edited with Banta). Dr Gray chaired the Middle States Association Commission on the Higher Education Advisory Panel on Student Learning and Assessment that produced the publication, *Student Learning Assessment: Options and Resources*. He has also given approximately 100 workshops, keynote addresses and presentations at conferences and on individual campus worldwide concerning topics related to the enhancement of higher education excellence.

**Conference Proceedings of the
10th UICEE Annual Conference on Engineering Education
under the theme:
*Reinforcing Partnerships in Engineering Education***

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