Modification of Value Rubrics for Engineering

Milica Marković
Department of Electrical and Electronic Engineering
California State University Sacramento
Sacramento, CA
milica@csus.edu

***Abstract*—This Innovative Practice Work In Progress Paper will discuss the alignment and modification of three VALUE Rubrics: Critical Thinking, Writing and Problem Solving. Performance Criteria from Benchmark to Capstone are described and used to assess student work in engineering laboratory. Preliminary results from implementation of the rubric on a junior-level antenna design project will be presented. Based on faculty feedback, the rubrics are currently further simplified, modified and will be applied again this semester. Description of pilot project to implement modified Value rubrics in Canvas LMS Student Learning Outcomes (SLO) will be briefly discussed.**

***Index Terms*—ABET, VALUE, LEAP, CANVAS**

I. Introduction and Background

In 2005, the Association of American Colleges & Universities (AAC&U) established Liberal Education and Americas Promise (LEAP) essential learning outcomes [1]. LEAP outcomes are: 1. Knowledge of Human Cultures and the Physical and Natural World (K), 2. Intellectual and Practical Skills (IP), 3. Personal and Social Responsibility (PS) and 4. Integrative and Applied Learning (IL). In 2009, AAC&U developed a set of 16 competencies described by VALUE rubrics [2] that can be used to assess LEAP outcomes. VALUE rubrics consist of 5-6 criteria, or dimensions, that further describe each VALUE competency through 4 performance descriptors. Each performance descriptor is assigned a performance level, from Benchmark 1 to Capstone. In this paper the performance levels are described from "Below Criteria" to "Exceeds Criteria".

The Accreditation Board for Engineering and Technology (ABET) established Engineering Criteria 2000 (EC 2000) in 1997 [3]. At the time, describing what students know and are able to do, instead of what is taught, was a revolutionary idea and was described as one of Five Major Shifts in 100 Years of Engineering Education by Froyd et. al. [4]. In October 2017 ABET condensed the number of outcomes from 11 to 7.

II. Alignment from University to Assignment outcomes

Alignment between University, Program and Course outcomes is usually outlined with curriculum alignment maps, [5]. Coney in [7] and Eppes [8] discussed possible alignment of ABET 2000 Student Learning Outcomes to Value Rubrics. In this work, the alignment is proposed from the University LEAP Goals to 2017 ABET SLOs, and further to the Course and Assignment Outcomes through modifications of VALUE rubrics. An example of potential alignment of LEAP Goals, VALUE rubrics and 2017 ABET student learning outcomes is shown in Table I. Some criteria of Critical Thinking, Problem Solving and Quantitative Literacy can be applied in some form to all ABET SLOs. Table I provides Engineering Colleges an ability to align ABET outcomes to both University goals on one side, and Course Outcomes on the other. The alignment provides faculty with example criteria and initial definition of VALUE rubric performance descriptors that should be further modified to reflect requirements for specific assignments. Using the criteria from VALUE rubrics, with modified performance descriptors, can be used to clearly align the assignment outcomes to Course, Program and University outcomes.

TABLE I
VALUE rubrics alignment to 2017 ABET Outcomes

	ABET SOs	*VALUE Rubrics*	*LEAP*
1	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	Quantitative Literacy, Problem Solving, Creative and Critical Thinking	**K**
2	an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	Quantitative Literacy, Problem Solving , Creative and Critical Thinking, Inquiry and analysis, Integrative learning	**K, IL**
3	an ability to communicate effectively with a range of audiences	Written and Oral Communication, Information Literacy	**IP**
4	an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	Ethical Reasoning, Global Learning, Intercultural Knowledge and Competence, Civic Engagement	**PS**
5	an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	Teamwork	**IP**
6	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	Quantitative Literacy, Problem Solving, Creative and Critical Thinking	**IP**
7	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	Life-long Learning	**PS**

In Electromagnetics laboratory course at Sacramento State,

978-1-5386-1174-6/18/$31.00 ©2018 IEEE

alignment of University, ABET (Program), Course and Assignment Learning Outcomes was defined through VALUE rubrics.

LEAP outcome 1 is aligned with ABET program outcome 2, and further to Course Outcome “Students will be able to design circuits using practical considerations and a major high frequency CAD tool” and patch antenna design Assignment Outcome 2:”Students use contemporary CAD tools to design and analyze microstrip transmission lines, matching circuits and patch antenna”. Modified Critical Thinking and Problem Solving VALUE rubrics are used to evaluate this outcome.

LEAP outcome 2 is aligned to ABET outcome 3 and further to Course Outcome 4 “Students will be able to write concise laboratory reports” through Assignment Outcome 3 “Students will write a patch antenna report to describe and demonstrate all steps in an engineering problem-solving process”. Writing VALUE rubric is used to evaluate this outcome.

LEAP outcome 2 is also aligned with ABET outcome 6 and further to Course Outcome 1 “Students will design and conduct high-frequency experiments and analyze and interpret data” through Assignment Outcome 1 “Students will fabricate and measure an antenna using a circuit router, network analyzer, and an anechoic chamber”. Modified Critical Thinking and Problem Solving VALUE rubrics are used to evaluate this outcome.

Modifying performance descriptors of VALUE rubrics, interpreting the criteria with the discipline-specific language, while keeping the spirit of the individual criteria and the same performance levels across all programs, allows for the alignment and data collection at the program and university level. Collection of data at the university level further enables the potential use of technology for criteria-specific, university-level direct assessment of student work.

III. Using Technology to Align Outcomes

In order to have a sustainable assessment process, faculty workload cannot increase, data collection must be easy and direct evidence of student work must be used. The Canvas Learning Management System (LMS) Student Learning Outcome (SLO) feature can provide an easy, automatic course data collection at the Department level. In Canvas, special department-level Canvas accounts with administrator privileges can be established. Departments then upload Program Outcomes to the Department-level Canvas account using SLO feature. In Canvas, SLOs have special “target” sign next to them. One way outcomes can be evaluated is by using specific VALUE rubric criteria as shown in the previous section. So, either actual Program Outcomes or VALUE rubric criteria aligned to specific Program Outcomes can be imported in Canvas as SLOs. Faculty in the department can then download the Program Outcomes or VALUE rubric criteria to the assignment rubrics in their Canvas courses. In a specific course, Canvas can display the grade as well as the performance of students and the entire class by outcomes. Students can also track progress of both SLOs and their grades. Once faculty are done grading assignments using Canvas SLOs, the data is automatically aggregated by Canvas LMS at the department level.

Canvas SLOs are aggregated at the Department level for individual students, however, not even the rudimentary course data analysis is available. Departments can provide statistical data analysis on student performance for the entire program by exporting data from Canvas into an external software specialized in data analysis. One such implementation that collects evidence of student work from Canvas courses and other sources to the University level is done by the Office of Assessment at Kansas State University [6].

The SLOs uploaded at the Department level are fixed, and cannot be modified by the faculty once imported to a course. An ability for faculty to modify performance descriptors for specific SLOs at the course level would be beneficial. More flexible assessment modules that can be implemented in Canvas are available from Portfolium [9] and Campus Labs [10], however, they come with additional cost.

Modification of VALUE rubrics for engineering is discussed next.

IV. Modification of VALUE Rubrics for Engineering Courses

In this section modified VALUE rubrics are presented together with preliminary application results of grading of 75 student reports. Percentages show the sum of meets and exceeds criteria.

A. Criteria for Engineering Critical Thinking **CT** *Rubric*

Students will be able to:

1) **CT1:** Explanation of issues - Explan antenna’s design equations, simulations, and measurements. *66%*

Exceeds Criteria: Thorough explanation of all equations, simulations, and measurements show deep comprehension of the problem.

Meets Criteria: Explanation of all equations, simulations, and measurements is present and correct, with very few omissions.

Meets Minimum Criteria: Most explanations are present, and some may have reasoning flaws.

Below Criteria: Explanations are not present, or they are presented but it is difficult to understand.

2) **CT2:** Evidence - Design can be replicated from the report. The evidence is correctly read and interpreted from data sheets, simulations circuit diagrams and results, fabrication and measurements. 63%

Exceeds Criteria: Procedures appear to be replicable. Steps are outlined sequentially and are adequately detailed. Thoughtful comments contribute to comprehension.

Meets Criteria: Procedures appear to be replicable. Steps are outlined and are adequately detailed. Comments are correct, and very few omissions are acceptable.

Meets Minimum Criteria: All steps are outlined, but there is not enough detail to replicate all procedures. Some comments on evidence are either missing or inconsequential.

Below Criteria: Several steps are not outlined and there is not enough detail to replicate procedures.

3) **CT3:** Influence of Context and Assumptions - Simplification of complexity, comparison of design, simulation and measurements is discussed and differences are explained. 36%

Exceeds Criteria: Experimental/Simulation errors, their possible effects, and ways to reduce errors are discussed.

Meets Criteria: Experimental/Simulation errors and their possible effects are discussed.

Meets Minimum Criteria: Experimental/Simulation errors are mentioned. There is no discussion of errors even though they are present.

Below Criteria: There is no discussion of errors or the discussion is incoherent or inconsequential.

4) **CT4:** Conclusion - Students will be able to evaluate antenna project, place evidence in perspective, reflect on the design in terms of related outcomes from design: simulations, fabrication, and measurements. 74%

Exceeds Criteria: Conclusions and related outcomes (design, comparison of simulated and measured results, manufacturing) are logical and reflect students informed evaluation and ability to place evidence and perspectives discussed in priority order. A thorough explanation of what could have been done better and how, and what needs further evaluation.

Meets Criteria: All conclusion items are covered with some depth and accuracy. Explanation of what could have been done better and how is mentioned.

Meets Minimum Criteria: Some conclusion items are covered but lack depth. Future work is briefly mentioned but it is inadequate or vague.

Below Criteria: Conclusion items are inaccurate, inconsequential or vague.

B. Criteria for Engineering Problem Solving **PS** *Rubric*

Students will be able to:

1) **PS1:** Define Problem - Define reasonable and relevant antenna specifications based on "customer need". 74%

Exceeds Criteria: Defines all relevant specification such as frequency, size, power transfer, specific matching circuits, power handling, weather effects, aerodynamic constraints, metal corrosion, sensitivity to manufacturing tolerances, durability, weight, flexibility, and cost) is considered if relevant.

Meets Criteria: Required specifications are defined such as frequency, size, power transfer, power handling are considered. Antenna Design is stated, and some design issues are identified. Applications are noted.

Meets Minimum Criteria: Specifications for the frequency of operation is mentioned.

Below Criteria: Specifications are missing or are incorrect.

2) **PS2:** Identify Strategies- Identify strategies to design an antenna prototype, for example, materials, circuit size, impedance matching circuit type, simulations, manufacturing process and measurement are all accurately selected. 78%

Exceeds Criteria: Discusses and proposes one or more strategies that indicate a deep comprehension of the problem, such as selection of substrate, connectors, bandwidth, sidelobes, matching, measurements. Plan for antenna development considers possible alternative strategies

Meets Criteria: Discusses and proposes one or more strategies such as selection of substrate, connectors, bandwidth, sidelobes, matching, measurements. Plan for antenna development is correct.

Meets Minimum Criteria: Discusses strategy that indicates comprehension of the problem, but many strategies are not considered or they may be flawed.

Below Criteria: Student struggles to identify strategies to solve the problem. Some strategies are considered, but they may be flawed, irrelevant, or inconsequential.

3) **PS3:** Propose Solution - Design an antenna prototype using appropriate design strategies, equations and calculations. 70%

Exceeds Criteria: Proposes one or more solutions of the problem, uses appropriate strategies, equations and calculations. Strategies, equations and calculations are correct.

Meets Criteria: Specific solution of the problem is selected and proposed, appropriate strategies, equations, and calculations, very few may be incorrect.

Meets Minimum Criteria: Solution is presented, but equations or calculations may be missing or incorrect.

Below Criteria: Student struggles to specify solution of the problem.

4) **PS4:** Evaluate Solution - Propose and fine-tune equations and calculations through engineering simulation and other tools. 61%

Exceeds Criteria: Simulations are comprehensive and show the depth of understanding. Circuit diagrams and plots are included and are labeled. Some diagrams are not referred to in the text one figure is difficult to read.

Meets Criteria: Simulations are comprehensive. Circuit diagrams and plots are included and are labeled. Some diagrams are not referred to in the text one figure is difficult to read.

Meets Minimum Criteria: Simulations are present, but may not be comprehensive. Circuit diagrams are included and but not labeled or some figures are difficult to read.

Below Criteria: Simulations are inconsistent with design equations, many items are missing such as circuit diagrams or simulation results.

5) **PS5:** Implement Solution - Make a layout, manufacture antenna prototype and perform appropriate measurements. 77%

Exceeds Criteria: Implements the layout in a manner that addresses thoroughly and deeply multiple contextual factors of the problem, such as materials/devices available, optimal material/devices, the optimal frequency of operation, optimal matching circuit, antenna size. Chosen strategy to implement solution is appropriate and reasonable, knowledge is used correctly

Meets Criteria: Layout is present and some contextual factors of the problem are addressed, such as materials available, optimal materials, the optimal frequency of operation, optimal matching circuit, antenna size. Chosen strategy to implement solution is appropriate and reasonable, knowledge is used correctly, except for few minor flaws.

Meets Minimum Criteria: Layout is submitted but there is no information about material or layout is shown in ADS but Geber printout is missing, or vice versa. There are many flaws in the chosen layout, such as missing dimensions, no silkscreen, etc.

Below Criteria: Layout is just submitted with no supporting information.

6) **PS6:** Evaluate Outcomes - Students will make, and evaluate appropriate measurements. 54%

Exceeds Criteria: Steps are outlined sequentially and are adequately detailed. Thoughtful comments contribute to comprehension.

Meets Criteria: Steps are outlined and are adequately detailed. Comments are valuable and contribute to comprehension.

Meets Minimum Criteria: All steps are outlined, but there is not enough information to evaluate outcomes. Some comments on evidence are either missing or inconsequential.

Below Criteria: Many steps are not outlined, there is no detailed information, the evidence is missing, or outcomes are not discussed.

C. Criteria for Engineering Writing **WR** *Rubric*

Students will be able to:

1) **WR1:** Context and Purpose of Writing - Write concise and informative technical report for the audience of peers. *66%*

*Exceeds Criteria:*Antenna Design is clearly stated, sufficiently detailed for a peer audience, and design issues are identified. The report uses headings to visually organize the material.

Meets Criteria: Antenna Design is stated, and some design issues are identified. The lab report is written, and formatting visually organizes the material.

Meets Minimum Criteria: Design issues are not mentioned. The report is either too verbose or missing important pieces. Formatting does not help visually organize the material.

Below Criteria: Antenna Design is considered in a superficial or verbose and irrelevant manner. Formatting is missing or report looks disorderly.

2) **WR2:** Content Development - Develop all parts of the antenna project report: design equations, simulations, measurements, comparison, conclusion. 76%

Exceeds Criteria: All required elements are present and effectively organized. (Objectives, Intro, Design, Simulation, Fabrication, Measurements, Comparison, Conclusion). Information in each section is organized in a logical manner and the purpose of each section is defined. Precise, technical vocabulary is used.

Meets Criteria: All required elements are present, with some minor omissions.

Meets Minimum Criteria: Several components are missing, or inaccurate. The report is disorganized, unclear or ineffectively presented.

Below Criteria: Required sections are missing or irrelevant.

3) **WR3:** Genre and Disciplinary Conventions - Appropriately display antenna design equations, simulations, measurements and resulting data in accurate figures, plots, and diagrams. All data is accurately labeled. 64%

Exceeds Criteria: Data is captured in tables and/or graphs. Axes, graphs, and tables are labeled and titled with appropriately sized fonts. The quantitative results are skillfully, but concisely presented and edited. Measurement setup used in the experiment is clearly and accurately described.

Meets Criteria: Data is captured in tables and/or graphs. Graphs and tables are labeled and titled. Very few omissions such as axes not labeled. Measurement setup used in the experiment is described.

Meets Minimum Criteria: Data is included, but some graphs or tables are presented. Some graphs may be lacking labels. Measurement setup used in the experiment is mentioned but not described.

Below Criteria: Data not shown or inaccurate. Tables contain rows and rows of data that does not contribute to the understanding of the report. Axes, tables may have fonts that are not visible. Measurement setup is not mentioned and not described.

4) **WR4:** Control of Syntax and mechanics - Use concise technical language and vocabulary to convey meaning. 93%

Exceeds Criteria: Uses technical language that skillfully communicates meaning to readers with clarity and fluency, and is virtually error-free.

Meets Criteria: Uses technical language that communicates meaning to readers, few errors or typos are present. Few grammatical errors.

Meets Minimum Criteria: Uses language to communicates meaning, but it may have many grammatical errors.

Below Criteria: Multiple errors are present or grammatical errors obscure meaning.

V. Conclusion

The challenge of an effective assessment process is to provide ongoing, meaningful data to faculty, and meaningful, detailed feedback to students that show progress in attaining SLOs in a specific course. It is important to transition rubrics from specific disciplinary knowledge and towards competencies that describe thinking skills. VALUE rubrics give a framework for defining outcomes, criteria and performance levels in general terms from the university to program, course and assignment levels. Each program, discipline, and course can adapt the criteria to the language of the discipline. Further, technology can be used to simplify data collection and analysis.

VI. Acknowledgment

The author would like to thank Sacramento State's Office of Program Assessment (OAPA) for assigned time used in part to write this paper, OAPA Director Prof. Liu, OAPA Faculty Consultants Prof. Chung, Prof. Brooks, EE Prof. Rucker and Teaching Assistants Li and Ou for helpful discussions.

References

[1] AACU Leap Outcomes https://www.aacu.org/leap/essential-learning-outcomes

[2] Association of American Colleges & Universities, https://www.aacu.org/value-rubrics

[3] ABET,http://www.abet.org/about-abet/history/

[4] J. E. Froyd, P. C. Wankat, and K. A. Smith, ”Five Major Shifts in 100 Years of Engineering Education,” Proceedings of the IEEE, vol. 100, no. Special Centennial Issue, pp. 1344-1360, May 13, 2012.

[5] Allen, Mary J. Assessing academic programs in higher education. Bolton, MA: Anker Publishing Company, 2004.

[6] Kansas State University Assessment, http://www.k-state.edu/assessment/

[7] E. Cooney, “Adapting the VALUE Rubrics to ABET ETAC Outcomes A-K,” 121st ASEE Annual Conference & Exposition, Indianapolis, IN, June 15-18, 2014.

[8] Eppes, Tom A., Ivana Milanovic, and Fredrick Sweitzer. ”Towards liberal education assessment in engineering and technology programs.” Journal of College Teaching & Learning (Online) 9.3 (2012): 171

[9] Portfolium Assessment, https://portfolium.com/solutions/assessment

[10] Campus Labs, https://www.campuslabs.com/