TOWARDS AN INTUITIVE AND OBJECTIVE ASSESSMENT FOR PROJECT-BASED MODULES

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ABSTRACT

Assessing student design-implement skills in project-based modules integrated with CDIO framework has always been a challenging task to teaching staff. Even equipped with written rubrics, staff still assess the students' performances based on their own understanding of observed students' achievements as well as staff's own interpretations of the given rubrics, which may vary from one teaching staff to another. This challenge is heightened for modules that have a large number of classes and involve more than 20 teaching staff, comprising both full-time and adjunct lecturers. The traditional rubrics often expect teaching staff to award marks ranging from 0 to 100 or from 0 to a preset maximum score. In reality, it is almost impossible to provide an equal number of different assessed works of students in different assessment fields to reflect that range of marks.

This paper thus examines how an intuitive and objective assessment for one such project-based module - Introduction to Engineering. By applying this model, the teaching members of IE can simply match all the possible observable project criteria from a dropdown list of descriptors such as "Optimal and neat layout", "Good and neat layout" …etc. for learning outcomes relating to design-implement skills. There is no need to specifically ensure that each assessment field has the maximum score when assessing. For any possible ambiguous interpretations, photos of past students' work were captured and presented in another spreadsheet for reference. The work has also taken into account feedback and comments from 15 teaching staff, collected via a questionnaire and another 4 via causal conservations. After evaluating the usefulness of the assessment, a few missing observable criteria have been suggested for inclusion in the improved version of the assessment. Teaching staff commented on the ease of use and intuitive aspects of the assessment provided. Through visual inspection of the submitted projects done by the students, teaching staff only need to select the matching appropriate descriptors from the dropdown list provided in an excel spreadsheet. Most importantly, the teaching staff can also now make use of the descriptors to provide quick and meaningful feedback to students to support their learning.

KEYWORDS

learning assessment, project-based module, feedback, gradebook, design skills, implement skills, observable record, observable performance. CDIO Standards 11, 12

NOTE: Singapore Polytechnic uses the word "courses" to describe its education "programs". A "course" in the Diploma in Electrical and Electronic Engineering consists of many subjects that are termed "modules"; which in the universities contexts are often called "courses".

BACKGROUND

Ever since the C-D-I-O approach has been adopted as the teaching methodology in Singapore Polytechnic, changes were made to the syllabi to incorporate the CDIO skills to develop the students' personal and professional skills and attributes; interpersonal skills of teamwork and communication; and system and product building skills. (Crawley et al. 2014; Pee S.H. & Leong H. 2005; Pee S.H. & Leong H. 2006, Leong H., Sale D. & Wee C.S.P. 2009)

In the School of Electrical and Electronic Engineering (SEEE), an Introduction to Engineering (IE) module was instituted in line with the CDIO model to introduce all the first year students (~800) to the field of engineering focusing on design-build experience. The module was designed with a strong focus on active experiential learning (Felder, 2009) which in turn aims to stimulate interest in and to strengthen motivation in students in the field of engineering through real world build-and-design activities. At the same time, students are given the opportunity to develop interpersonal skills of teamwork and communication while developing the basic skills of circuit board prototyping. It is expected that this learning method will improve students' learning outcomes and encourage students to develop cognitive and psychomotor skills.

The module runs for 4 hours a week for a total of 15 weeks in the laboratory environment every first semester of the year. The module comprises 40% summative assessment, 20% on assessing teamwork, communication and interpersonal skills with the remaining 40% on the design and build project work as shown in Figure 1.

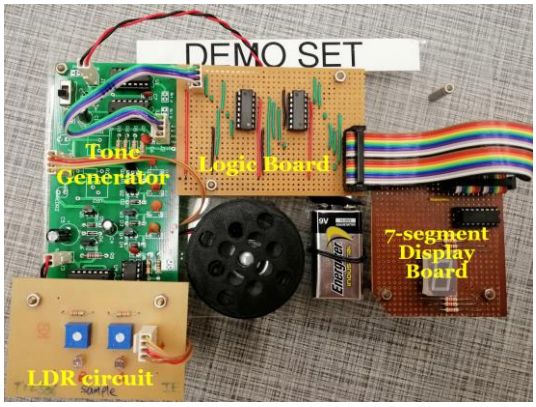


Figure 1. The complete project where students need to design, build, test and submit

Accordingly to Leong H., Sale D. & Wee C.S.P., (2009), the selected CDIO skill set has been implemented and has been sufficiently well received by both students and teaching staff. A number of assessment components were also developed to assess students' various skills to match the learning outcomes. Of all the assessment components, assessing student design-implement skills for the project work that weights 40% in total has always been an ongoing challenge to ensure reliability with the use of the given rubrics. To effectively illustrate how the design-implement skills were assessed in this module, let's look at a specific learning activity where a student is expected to learn the basic skills and techniques of circuit prototyping via their first circuit. For the sequent activities, the students were then expected to transfer what they have learnt to design and make their second board.

In this activity, students were told to build a simple 7-segment display board using a stripboard as shown in Figure 1 with the schematic diagram given in Figure 2.

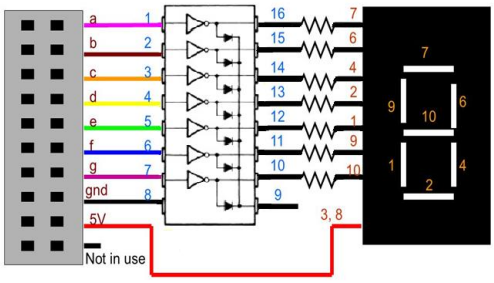


Figure 2. A simple 7- segment display schematic diagram.

As this is their first circuit board, the learning outcomes of this specific activity focus on the following:

- Understand the operation of the circuit diagram.
- Plan and assemble the components on a strip board to create a circuit.
- Able to apply the techniques of soldering and desoldering to an acceptable standard.
- Analyse the circuit and demonstrate the ability to trace the circuit board using the schematic diagram.
- Integrate and troubleshoot the project using appropriate instrument(s).

After the student has completed fabricating the board, he is then expected to test the board using a test board provided in the lab. The staff would then assess the student's performance with the given assessment rubrics as shown in Table 1.

Table 1. Scoring Rubrics for the 7-segment display board

Ability to construct the display board on stripboard and work independently (10 marks)	
0%-25%	Rarely.
25%-50%	Sometimes.
50%-75%	Often.
75%-100%	Very often.
Functionalities of the board (10 marks)	
0%-25%	Does not complete the task or task badly done.
25%-50%	Partially working circuit with much assistance.
50%-75%	Working circuit with some assistance.
75%-100%	Complete the task successfully and independently.
Overall workmanship of the completed project (ie good solder joints, components and cables are neatly laid out and connected) (5 marks)	
0%-25%	Does not complete the task or task badly done
25%-50%	Only partially met to an acceptable standard
50%-75%	Mainly met to an acceptable standard
75%-100%	Mainly met to a high standard

However, such generic descriptive scoring schemes often result in differences in marking for the same piece of work. The differences in mark can arise from a number of sources (José-Luis Menéndez-Varela & Eva Gregori-Giralt, 2018; S. Bloxham, 2009; J. Archer & B. McCarthy, (1988) ;B. McKinstry, H Cameron, R Elton & S Riley, (2004).

One common source is that individual lecturers will assess their students' performances based on their own understanding of students' observed achievements as well as staff's own interpretations of the given rubrics, which may vary from time to time and from one teaching staff to another. Two, as seen from the scoring rubrics, some of the assessment components (in this case, the workmanship was assessed at the end of the day) was assessed after the whole project which consisted of a few boards (see Figure 1), was completed. This makes it difficult even for one staff to maintain consistency as the students may have very different performance for different boards with varied levels of complexity. There are also teaching staff who tend to be more lenient in awarding marks than the presented work should deserve due to the time and effort the student had put in. All these become particularly evident whenever there is a group of staff coming together to assess the students' project work during an event or funded projects in our school. Staff have shown to present different views and differing levels of knowledge. This can thus result in varying expectations of students' level of understanding and emphasis may be on different aspects of the presented work. Another common source of error can arise from a lack of subject familiarity. All these challenges were heightened for this particular module as it involved about 40 classes each year with more than 20 teaching staff, comprising both full-time and adjunct lecturers.

Challenges

Establishing reliability is a prerequisite in accurate measurements of learning outcomes. When the results of an assessment are reliable, one can be confident to make generalised statements about a students' level of achievement, which is especially important when we are using the results of an assessment to make decisions about teaching and learning. However, there are few challenges which we should take note when redesigning the students' assessment. They are:

- Lecturers universally agreed that CDIO implementation has resulted in an increase in workload, resulting from the preparation and assessment involved, especially when cohort size is large and there are a number of assessment components (Felder, R. ,2009). This means having multiple markers or double-blind marking as suggested by K. Willey & A. Gardner (2010) in an effort to achieve consistent grading is not realistic. Thus, if possible, scoring rubrics should be made simple and easy to follow without overwhelming the teaching members. This is particularly important in communicating to the students the rubrics as well as helping adjunct lecturers and new teaching members to cope with the workload.

- Improving the marking rubrics with more specific description is possible. However, the traditional rubrics often expect teaching staff to award marks ranging from 0 to 100 or from 0 to a preset maximum score. When there isn't sufficient different observable works of students to reflect the range of possible marks, this can produce a wider difference in the marks awarded.

DEVELOPING RELIABLE AND EASY-TO-USE ASSESSMENT

In order to redesign an assessment that is easy to follow and coherence to learning outcomes, we first break down the project into pieces of work as shown in Table 2 with reference to Figure 1. Based on the relative difficulty and importance of work, the individual boards were weighted accordingly as shown in Table 2.

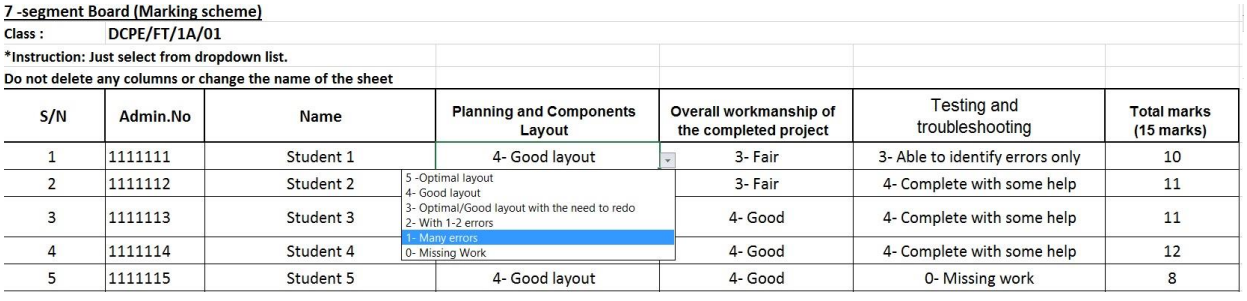
Next, a self-learning guide with clear learning outcomes for the students was developed (see Appendix B). The learning guide serves dual purposees. Firstly, it provideesopportunities for students to be more independent in their work and be able to self-assess their own hands-on work. This is especially useful during last semester (around March to June 2020) when Singapore entered into CircuitBreaker shutdown due to Cov19. Secondly, it is easier for all the teaching staff to communicate to students their expectations and how their work is being assessed. As the self-learning guide is another piece of teaching and learning work, details on the effectiveness and how it was designed will not be discussed here.

Table 2. Boards that make up the final project and their weighted score.

Sequence	Breakdown of the boards to be submitted at the end of the day	Projected level	Weightings
1	The 7–segment display board	Easy	12%
2	Logic board	Intermediate	25%
3	LDR circuit & Tone generator	Easy	8%
		Total	40%

Using past experience, observations and collection of past students' work, all the possible observable project criteria was then listed. To illustrate, one can refer to Appendix A for the evaluation criteria for the 7-segment board. For any possible ambiguous interpretations, photos of past students' work were captured and presented in the same marking spreadsheet for reference. The marking scheme also provide some room for flexibility to the lecturers when assessing skills such as troubleshooting skills to ensure validity. This is because troubleshooting skills can be demonstrated at different level and depth. It also make the assessment more resilient when there is some allowance for changing conditions.

Once the evaluation criteria was established, Excel spreadsheet was then designed to capture all the evaluation criteria, weights and scores. To make the whole assessment process easy and intuitive, a drop down list with all the project criteria such as "Optimal and neat layout", "Good and neat layout" …etc. was listed. Figure 3. Show a screenshot on what a lecturer would see while using the spreadsheet for assessment.



7 -segment Board (Marking scheme)

Class : DCPE/FT/1A/01

*Instruction: Just select from dropdown list.

Do not delete any columns or change the name of the sheet

S/N	Admin.No	Name	Planning and Components Layout	Overall workmanship of the completed project	Testing and troubleshooting	Total marks (15 marks)
1	1111111	Student 1	4- Good layout	3- Fair	3- Able to identify errors only	10
2	1111112	Student 2		3- Fair	4- Complete with some help	11
3	1111113	Student 3		4- Good	4- Complete with some help	11
4	1111114	Student 4		4- Good	4- Complete with some help	12
5	1111115	Student 5	4- Good layout	4- Good	0- Missing work	8

5 -Optimal layout
4- Good layout
3- Optimal/Good layout with the need to redo
2- With 1-2 errors
1- Many errors
0- Missing Work

Figure 3. Screenshot of the scoring rubrics for the 7-segment board in an Excel spreadsheet.

FEEDBACK FROM TEACHING STAFF

About two weeks after the end of the semester, an online survey were emailed to all the 24 teaching staff to gather feedback after using the new assessment spreadsheet. The questionnaire consists of a total of 6 items and the participants were asked to rank the first 4 items on a 5 point likert-type scale (1=strongly disagree to 5=strongly agree). The last 2 items are open ended questions. Staff were also given the option to call or arrange a meet up to discuss if they have any ideas for further improvement. The results for the first 4 items and the collected responses from the last 2 items are shown in Table 3 and Table 4 respectively.

Table 3. Teacher Staff Survey Results for item 1 to 4

No.	Question	Average Rating
1	The use of the “new” excel marksheet using the drop down list is easy and intuitive to use.	4.67
2	I find the new marksheet allows me to maintain better consistency in assessing student's performance as compared to the traditional marksheet.	4.53
3	The description of the different levels of competence seen from the drop down list is clear and well organized.	4.33
4	The description on the drop down list helps teaching staff to provide a useful and consistent feedback on student performance.	4.40

Table 4. Teacher Staff Survey Results for item 5 and 6

No.	Question	Responses
5	Do you think there is any competency level not captured in the marksheet? (You can email to me later if you need more time to think about it)	*students who take shorter time to complete the project. "* *"For Logic bd design, assess if students can optimize the design (i.e. use min number of logic gates) "* *"nothing is perfect in this world, although it's already very well done, there is always room for further improvements. You already did a fantastic job"*
6	Do you think there is a better way to improve the current assessment for project based modules? Do send us your ideas and suggestions. (e.g freeze panes to ease scrolling up and down or all the way to providing assessment that impacts learning.)	*in competency level, to include if the board is completed and working, partially working? "* *"no need to picking bone from egg."*

Though only 15 out of 24 teaching staff completed the survey, all but one gave the 5 or 4 as their responses to all the first 4 items. This clearly indicates that all find it easy to use, find the description clear and help them to provide consistent feedback on student performance.

The only item that received a low score of 2 was item 2. This means 1 out of 15 respondents did not agree that the new scoring rubrics help to maintain better consistency compared to the

past rubrics. The comments were mostly valid as well, indicating improvement can be made by including the missed out criteria components. In addition to the 15 staff who did the survey, there were 4 staff who actually preferred to have a causal discussion with me on how the assessment can be further improved. These four staff members all commented that the assessment saved their time in the assessment and it was intuitive and easy to use. However, they found that a few observable criteria were missing and should have been included in the improved version of the assessment for the next run. The missing criteria mainly include the timely completion of the project, including more levels on the board completion and should reward students when they have shown to complete the project in the short time or uses very little resources to complete them. All these are valid and thus will be included in the improved version as shown in Appendix A for the 7-segment scoring rubrics.

CONCLUSIONS

The paper firstly discussed the challenges of ensuring reliable assessment with a large class size and having more than 20 teaching members. The use of an intuitive and objective assessment for the module – IE1 was then presented. Using the new assessment rubrics on Excel, teaching members only need to match students' submitted project/performance with all the possible observable project criteria from a drop down list of descriptors such as "Optimal and neat layout", "Good and neat layout" …etc. Such a carefully designed simple, task specific, scoring rubrics does not need to have the assessment field that share the same maximum score has the potential to produce increased reliable assessment. Majority of the teaching staff had also feedback that it is easy to use and require no pre-training. The dropdown list also helped teaching staffs to give very quick and consistent feedback. However, some criteria that was observed by teaching staffs were missing. Room for increased flexibility such as having different levels of board completed should be included as well to ensure validity of the assessment.

Though this approach not necessarily can overcome individual biases in the scoring (J. Archer & B. McCarthy,1988), the act of selecting the most matching appropriate descriptors from the drop down list provided in spreadsheet while inspecting a student's submitted work can help to average some of these effects. The author was also happy to find that teaching members do not find the use of the new assessment as an extra work. Quite a number even verbally told me it is time saving as there is less chances for them to remark to maintain consistency. Moving forward, the author will continue to improve the assessment by including the missing criteria making it more valid and reliable. This also include the possibility of gathering all the staff's grading spreadsheet to perform do a comparative analysis against some summative assessment the students are taking. We may also explore getting student to perform their own evaluation using the same rubrics. In this manner, we can then understand if the student understand the assessment criteria and the staff expectations of their work.

After all, more and more schools are using assessment data to help them make decisions. Thus, having easy to interpret, reliable and valid learning outcomes is always the first step.

REFERENCES

Bloxham.S, (2009) Marking and moderation in the UK: false assumptions and wasted resources, *Assessment and Evaluation in Higher Education, Vol. 34, No.2, pp 209-220.*

B. McKinstry, H Cameron, R Elton & S Riley, (2004). Leniency and halo effects in marking undergraduate short research projects, *BMC Medical Education*, Vol. 4, No.28, 2004. Available online at http://www.biomedcentral.com/content/pdf/1472-6920-4-28.pdf

Crawley, E., Malmqvist, J., Östlund, S., Brodeur, D., & Eström, K. (2014). Rethinking engineering education: The CDIO approach (2nd ed.). New York: Springer.

Felder, R. (2009). *Active Learning: An Introduction*. ASQ Higher Education Brief, 2(4).

J. Archer & B. McCarthy, (1988) Personal biases in student assessment, *Educational Research,* Vol. 30, No. 2, pp142-145, 1988.

José-Luis Menéndez-Varela & Eva Gregori-Giralt (2018) The reliability and sources of error of using rubrics-based assessment for student projects, *Assessment & Evaluation in Higher Education, 43:3, 488-499*.

K. Willey & A. Gardner, 2010. Improving the standard and consistency of multi-tutor grading in large classes, *ATN Assessment Conference*, Sydney, Australia.

Leong H., Sale D. & Wee C.S.P., (2009). Evaluating the Implementation of CDIO Programs at Singapore Polytechnic: The First Year, *5th International CDIO Conference,* Singapore.

Pee S.H. & Leong H., (2005). Implementing Project Based Learning using CDIO Concepts, *1st Annual CDIO Conference*, Ontario.

Pee S.H. and Leong H.,(2006). Reformulating Engineering Education in Singapore Polytechnic, *2nd International CDIO Conference,* Linkoping.

BIOGRAPHICAL INFORMATION

Chia Chew Lin, is the Academic Mentor of the School of Electrical and Electronic Engineering at Singapore Polytechnic. She loves to experiment with new teaching ideas to enhance students' intrinsic motivation in learning. Her current interests and focus is identifying the current learning problem or teaching ineffectiveness and work to improve on it.

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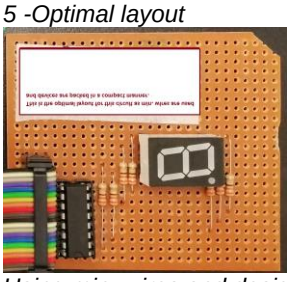
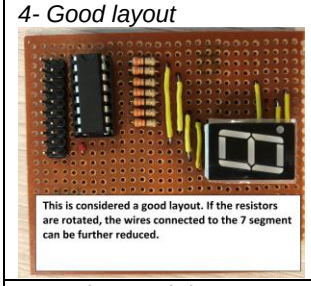
APPENDIX A

7 – segment board scoring rubrics		
Layout plan		
Evaluating Criteria	Marks	Improved Version
5 -Optimal layout  *Using min. wires and design is compact.*	5	-
4- Good layout 	4	-
3- Redo or Fair layout *i.e layout not as good as the first 2.*	3	-
2- With 1-2 errors	2	2- With 1-2 errors/ Partial Complete
1- Many errors	1	1- Many errors/Partial Complete
0- Missing Work	0	-
Overall workmanship		
Criteria:	Marks	Improved Version
5- Excellent *Wiring is neat and at appropriate length, use the correct color code, solder joints look shiny,…etc*	5	Not change.
4- Good	4	
3- Fair	3	
2- Poor/Partial complete	2	
1- Partial complete	1	
0- Missing work	0	
Testing and Troubleshooting		
Criteria:	Marks	Improved Version
5- Complete with min. guidance	5	8- Complete on time without help. 7 - Complete on time + min. guidance 6- Complete on time + little help. (e.g can identify errors but can't solve) 5 - Complete on time + some help (e.g can't identify all errors) 4- Partial Complete/not on time 3-Partial complete/not on time 2- Partial or Complete by getting others to troubleshoot for them frequently. 1-Get others to troubleshoot for them & not learning 0 -Missing work
4- Complete with some help	4	
3- Able to identify errors only	3	
2- Not trying enough/did not complete on time	2	
1- Rely on others & not learning	1	
0- Missing work	0	

APPENDIX B

7 –Segment Board
Self-Directed Learning Guide

To be successful in self-directed learning, one must be able to engage in self-reflection and self-evaluation of his/her learning goals and progress in a unit of study. To support your learning progress in IE1, we have created a list of learning milestones so that you are able to monitor and evaluate your own learning. If you can't achieve the learning milestones in your first attempt, don't get discouraged! List down the learning challenges in your BCA form! Discuss with your team member and lecturer and see what learning resources/strategies you need to overcome your learning challenges.

Name	
Admin No	

Learning goals: Learn the skills on how to make circuit on a stripboard
Completion Date:

While doing my layout planning, I am able to

- ☐ plan the position of the components so that it uses the connections already on the stripboard as much as possible. (i.e. less connecting wires)
- ☐ label the numbering of the ICs, Vcc and Ground, …etc clearly on the planning sheet.

For electrical safety & Housekeeping, I am able to

- ☐ setup the soldering working area in a safe manner.
- ☐ ensure electrical safety practices and perform basic tool and equipment housekeeping (e.g. turn off the power when not using, wires do not fly all over while stripping) at all times.

While fabricating the stripboard, I am able to

- ☐ use RED wire for Vcc.
- ☐ use BLACK wire for Ground.
- ☐ use coloured wires to represent logic lines.
- ☐ use proper wire length and layout my wiring in a neat manner.
- ☐ apply solder such that the soldered joints looks smooth, shiny and cling to the metals for proper connections.

Before I test the board,

- ☐ I have visually inspected the board to check if there are any soldering problems.
  I am able to use the digital multimeter to carry out the test procedures to check if
  - ☐ Vcc and Ground are not shorted.
  - ☐ all the tracks between the pins of an IC are not shorted after breaking them.
  - ☐ The logic inputs are not shorted (unless they are meant to)
  - ☐ The lCs are properly wired to Vcc and Ground.

While testing of the board, I am able to

- ☐ test the board and show the working piece to my lecturer.

While troubleshooting the board

- ☐ I am able to explain how the circuit works (revisit the lecture slides on how the circuit works).
- ☐ I am able to identify the problem encountered. e.g. LED segment b is not working as intended.
- ☐ I am able to use the digital multimeter to identify and trace where the problem lies.
- ☐ I have done all the necessary checking and testing before I seek assistance from my lecturer.

Lecturer in Charge: _____
Signature