EVALUATING EFFECTS OF CDIO IMPLEMENTATION ON DIPLOMA IN CHEMICAL ENGINEERING

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ABSTRACT

This paper will present the effects of Conceive-Design-Implement-Operate (CDIO) implementation on Diploma in Chemical Engineering (DCHE) at Singapore Polytechnic (SP). Firstly, the paper will provide an overview of why, when and how the CDIO education framework was implemented in DCHE. Secondly, the paper will outline the timeliness for DCHE to conduct the evaluation study to appraise the effects of CDIO implementation on DCHE so as to achieve CDIO standard 12. Thirdly, the paper will identify the key research questions that form the basis of the evaluation study, as well as the various SPSS data analysis techniques employed. Finally, it provides an appraisal of the results of the evaluation study, identifies key limitations of the evaluation methodology, as well as recommendations for future evaluation activities.

KEYWORDS

CDIO Implementation, Evaluation, SPSS, Standard 12.

OVERVIEW OF CDIO EDUCATION FRAMEWORK IN DIPLOMA IN CHEMICAL ENGINEERING

The myriad of teaching and learning challenges that are faced by polytechnic educators in Singapore today (Ng, 2014) prompted DCHE to adopt the CDIO education framework in 2007. Since then, DCHE has made tremendous efforts in aligning the DCHE curriculum to the CDIO standards in the CDIO education framework. Illustrations of the work done by DCHE to meet the various CDIO standards are shown in Table 1.

Based on Table 1, it is argued that six years since the CDIO implementation in DCHE, DCHE has managed to meet in large part all the CDIO standards except for standard 12. It is now timely to ascertain the impact of CDIO implementation on DCHE in a more systematic manner, through conducting an evaluation study.

Table 1: Work Done by DCHE to Satisfy Each CDIO Standard

	CDIO Standards	Work Done by DCHE
1	CDIO as context	Under the guidance of DCHE Course Management Team (CMT), DCHE conducted an extensive gap analysis in 2007 by comparing its curriculum against the 12 CDIO standards. Based on the gap analysis, DCHE then worked to bridge the gaps between its curriculum and the 12 CDIO standards.
2	CDIO syllabus outcomes	In 2007 and 2010, DCHE performed comprehensive mappings of all its modules to the various learning outcomes that are stipulated in CDIO Syllabus V1.0 and V2.0, respectively (Crawley, Malmqvist, Lucas and Brodeur, 2011). The mappings resulted in rewriting of DCHE module syllabi and redesigning of DCHE learning activities.
3	Integrated curriculum	As an illustration, CDIO learning outcomes of one DCHE module, *Introduction to Chemical Product Design*, are integrated with modules such as *Analytical and Physical Chemistry*, *Inorganic and Organic Chemistry*, *Teamwork and Communication Toolbox* and *Introduction to Chemical Engineering*.
4	Introduction to engineering	In 2008, DCHE rolled out an introductory module, *Introduction to Chemical Engineering*, which provides students with fundamental understanding of chemical engineering sciences and principles, as well as active and experiential activities that mimic real-world work typical of chemical engineers.
5	Design-implement (DI) experiences	As an illustration, there is a DI experience in one DCHE module, *Introduction to Chemical Product Design*, whereby students are required to design and construct their own water filters using limited available materials and budget.
6	CDIO workspaces	In 2010, a new workspace named W323 was created to support and encourage hands-on learning of DCHE disciplinary knowledge.
7	Integrated learning experiences	Student-focused instead of teacher-focused pedagogical approaches that are rooted in cognitive constructivism (Piaget, 1968) and social constructivism (Smagorinsky, 2013) have been adopted by DCHE faculty.
8	Active learning	
9	Enhancement of faculty CDIO skills	DCHE faculty regularly partake in sabbatical attachment programmes to local universities, research institutions and companies so as to keep abreast with latest chemical engineering knowledge and skills.
10	Enhancement of faculty teaching skills	DCHE faculty regularly attend education and pedagogical related conferences, seminars and workshops so as to enhance competency in teaching skills.
11	CDIO skills assessment	Greater formative instead of summative assessments of student learning have been adopted by DCHE faculty. Consequently, DCHE faculty have also created assessment rubrics to aid in formative assessments of student learning.
12	CDIO programme evaluation	No system is in place yet to evaluate effects of CDIO implementation on DCHE.

METHODOLOGY OF THE EVALUATION STUDY

It is important to note that the evaluation study is based on three major aspects, namely student performance, graduate performance and course performance. Research questions for each aspect of the evaluation study are delineated in Table 2, and definitions and elaborations of terminologies that are used in Table 2 are described in Table 3. Additionally, sources of the data that are collected for the evaluation study are listed in Table 4.

To evaluate the effects of CDIO implementation on DCHE in the aspect of student performance, overall mean marks and practical marks of *HTE* and *CRE* that are obtained by 240 DCHE students from six academic years (i.e. from 2007 to 2012) were collected. A sample of these data can be found in Appendix A.

In order to evaluate the effects of CDIO implementation on DCHE in the aspect of graduate performance, employment rate, mean monthly salary and further study percentage of DCHE graduates from 2007 to 2012 have also been collected (see Appendix B).

To evaluate the effects of CDIO implementation on DCHE in the aspect of course performance, DCHE cohort success rate and DCHE course satisfaction score from 2007 to 2012 are collected, and these data can be found in Appendix C.

Lastly, after gathering all the relevant data, the various SPSS data analysis techniques that have been employed in the evaluation study are illustrated in Table 5.

Table 2: Research Questions in the Evaluation Study

Aspects	Research Questions
Student performance	1. Are overall mean marks[A] of DCHE modules[B] significantly different from ideal test value of 75 before and after CDIO implementation in DCHE[C]? 2. Are overall mean marks of DCHE modules after CDIO implementation in DCHE significantly different from before CDIO implementation? 3. Are practical marks[D] of DCHE modules after CDIO implementation in DCHE significantly different from before CDIO implementation? 4. Are there correlations between practical and overall mean marks of DCHE modules before and after CDIO implementation in DCHE?
Graduate performance	1. Is employment rate[E] of graduates after CDIO implementation in DCHE significantly different from before CDIO implementation? 2. Is mean monthly salary[F] of graduates after CDIO implementation in DCHE significantly different from before CDIO implementation? 3. Is further study percentage[G] of graduates after CDIO implementation in DCHE significantly different from before CDIO implementation? 4. Are there correlations between employment rate, mean monthly salary and further study percentage of graduates before and after CDIO implementation in DCHE?

Table 2: Research Questions in the Evaluation Study (Cont.)

Aspects	Research Questions
Course performance	1. Is DCHE cohort success rate[H] after CDIO implementation in DCHE significantly different from before CDIO implementation? 2. Is DCHE course satisfaction score[I] after CDIO implementation in DCHE significantly different from before CDIO implementation? 3. Are there correlations between DCHE cohort success rate and DCHE course satisfaction score before and after CDIO implementation in DCHE? 4. Are there correlations between student performance, graduate performance and course performance?

Table 3: Definitions and Elaborations of Terminologies Used in Table 2

Terminologies	Definitions and Elaborations
A: Overall mean marks	A typical DCHE module comprises four assessment components, namely test, examination, practical and assignment. Hence, overall mean mark of a DCHE module refers to summation of each assessment component marks in the module.
B: DCHE modules	Two DCHE modules, namely *Heat Transfer and Equipment* (*HTE*) and *Chemical Reaction Engineering* (*CRE*) are chosen for the evaluation study. These two modules are selected as they are one of the most difficult modules in DCHE.
C: Before and after CDIO implementation in DCHE	Although CDIO education framework is adopted in DCHE in 2007, actual roll-out of DCHE modules that are embedded with CDIO is in 2009 as it took DCHE two years of preparatory work to rewrite its module syllabi and redesign its learning activities.
D: Practical marks	The redesigned learning activities of a typical DCHE module are reflected in the practical assessment component. Thus, it is important to evaluate effects of CDIO implementation on practical marks.
E: Employment rate	Employment rate refers to percentage of DCHE graduates who are able to find full-time employment within three months of their graduation.
F: Mean monthly salary	Mean monthly salary refers to mean monthly income of DCHE graduates who are in full-time employment.
G: Further study percentage	Further study percentage refers to percentage of DCHE graduates who are pursuing full-time degree programmes in local or overseas universities.
H: DCHE cohort success rate	DCHE cohort success rate refers to percentage of DCHE students who successfully complete their diploma programme in three years.
I: DCHE course satisfaction score	DCHE course satisfaction score refers to a feedback score by DCHE graduates and is based on a scale of 1 to 5, with 5 being the highest.

Table 4: Sources of the Data in the Evaluation Study

Aspects	Data Sources
Student performance	Student Administration System (SAS) – A proprietary SP database that contains academic information of all past and present SP students.
Graduate performance	Graduate Employment Survey (GES) – A proprietary SP database that contains information of SP graduates from annual surveys.
Course performance	Academic (ACAD) – A proprietary SP database that contains information of SP courses from annual surveys.

Table 5: SPSS Data Analysis Techniques Used in the Evaluation Study

Aspect	Research Questions (Refer to Table 2)	SPSS Data Analysis Techniques
Student performance	Question 1	One-sample t test
	Questions 2 and 3	One-way analysis of variance (ANOVA) and independent-samples t test
	Question 4	Pearson product-moment correlation coefficient
Graduate performance	Questions 1 to 3	Independent-samples t test
	Question 4	Pearson product-moment correlation coefficient
Course performance	Questions 1 and 2	Independent-samples t test
	Question 3	Pearson product-moment correlation coefficient
	Question 4	Multiple linear regression for path model

RESULTS OF THE EVALUATION STUDY

Student Performance

To begin with, results of the evaluation study in the aspect of student performance are summarised in Table 6. Hence, referring to Table 6, it is evident that effects of CDIO implementation on DCHE in the aspect of student performance (for Questions 1 and 3) are not consistent between the two selected DCHE modules (i.e. *HTE* and *CRE*).

One possible reason for the inconsistency can be due to the disparity in DCHE faculty's CDIO proficiency in adopting the CDIO education framework into their respective modules (Leong-Wee, Sale, Wee and Low-Ee, 2010). Moreover, in the context of this paper, it is also postulated that another possible reason for the discrepancy between *HTE* and *CRE* is due to the frequent change in DCHE faculty who is tasked to teach the *CRE* module.

Table 6: Results for the Evaluation Study in the Aspect of Student Performance

Research Questions		Significant Difference or Correlation?			
		HTE		*CRE*	
1	Are overall mean marks of DCHE modules significantly different from ideal test value of 75 before and after CDIO implementation in DCHE?	Before CDIO:	Yes	Before CDIO:	Yes
		After CDIO:	No	After CDIO:	Yes
2	Are overall mean marks of DCHE modules after CDIO implementation in DCHE significantly different from before CDIO implementation?	No		No	
3	Are practical marks of DCHE modules after CDIO implementation in DCHE significantly different from before CDIO implementation?	Yes		No	
4	Are there correlations between practical and overall mean marks of DCHE modules before and after CDIO implementation in DCHE?	Before CDIO:	Yes	Before CDIO:	Yes
		After CDIO:	No	After CDIO:	No

Next, referring to Table 6 again, it is possible that CDIO implementation shows no significant difference in student performance (for Question 2) for both *HTE* and *CRE* even though there may be significant difference in student performance (for Questions 1 and 3). Additionally, it is also perceptible that unlike before CDIO implementation, there are no correlations for student performance (for Question 4) after CDIO implementation.

Hence, it is hypothesised that one possible reason for the above results is due to the fact that DCHE faculty have only adopted the CDIO education framework in the practical component of their modules but not in the remaining components such as test and examination.

Graduate Performance

The results of the evaluation study in the aspect of graduate performance are displayed in Table 7.

At this juncture, it is important to note that though DCHE adopted the CDIO education framework in 2007, it took DCHE two years before the CDIO education framework was implemented into the DCHE curriculum. That is to say, first cohort of DCHE students who went through the CDIO-enabled curriculum was in 2009 and they graduated in 2012.

Thus, referring to Table 7, it is clear that effects of CDIO implementation on DCHE in the aspect of graduate performance (for Questions 1 to 4) are largely inconclusive due to the limited number of post-CDIO implementation data. Nonetheless, it is noticeable that prior to CDIO implementation in DCHE, there are actually no correlations between employment rate, mean monthly salary and further study percentage of DCHE graduates.

Table 7: Results for the Evaluation Study in the Aspect of Graduate Performance

	Research Questions	Significant Difference or Correlation?	
1	Is employment rate of graduates after CDIO implementation in DCHE significantly different from before CDIO implementation?	Inconclusive	
2	Is mean monthly salary of graduates after CDIO implementation in DCHE significantly different from before CDIO implementation?	Inconclusive	
3	Is further study percentage of graduates after CDIO implementation in DCHE significantly different from before CDIO implementation?	Inconclusive	
4	Are there correlations between employment rate, mean monthly salary and further study percentage of graduates before and after CDIO implementation in DCHE?	Before CDIO:	No
		After CDIO:	Inconclusive

Course Performance

Lastly, results of the evaluation study in the aspect of course performance are illustrated in Table 8.

Similar to that of graduate performance, effects of CDIO implementation on DCHE in the aspect of course performance (for Questions 1 to 4) are largely inconclusive due to the limited number of post-CDIO implementation data. Having said that, it is still very apparent that prior to CDIO implementation in DCHE, there are no correlations between DCHE cohort success rate and DCHE course satisfaction score.

Table 8: Results for the Evaluation Study in the Aspect of Course Performance

	Research Questions	Significant Difference or Correlation?	
1	Is DCHE cohort success rate after CDIO implementation in DCHE significantly different from before CDIO implementation?	Inconclusive	
2	Is DCHE course satisfaction score after CDIO implementation in DCHE significantly different from before CDIO implementation?	Inconclusive	
3	Are there correlations between DCHE cohort success rate and DCHE course satisfaction score before and after CDIO implementation in DCHE?	Before CDIO:	No
		After CDIO:	Inconclusive
4	Are there correlations between student performance, graduate performance and course performance?	Before CDIO:	Path model is created
		After CDIO:	Path model cannot be created

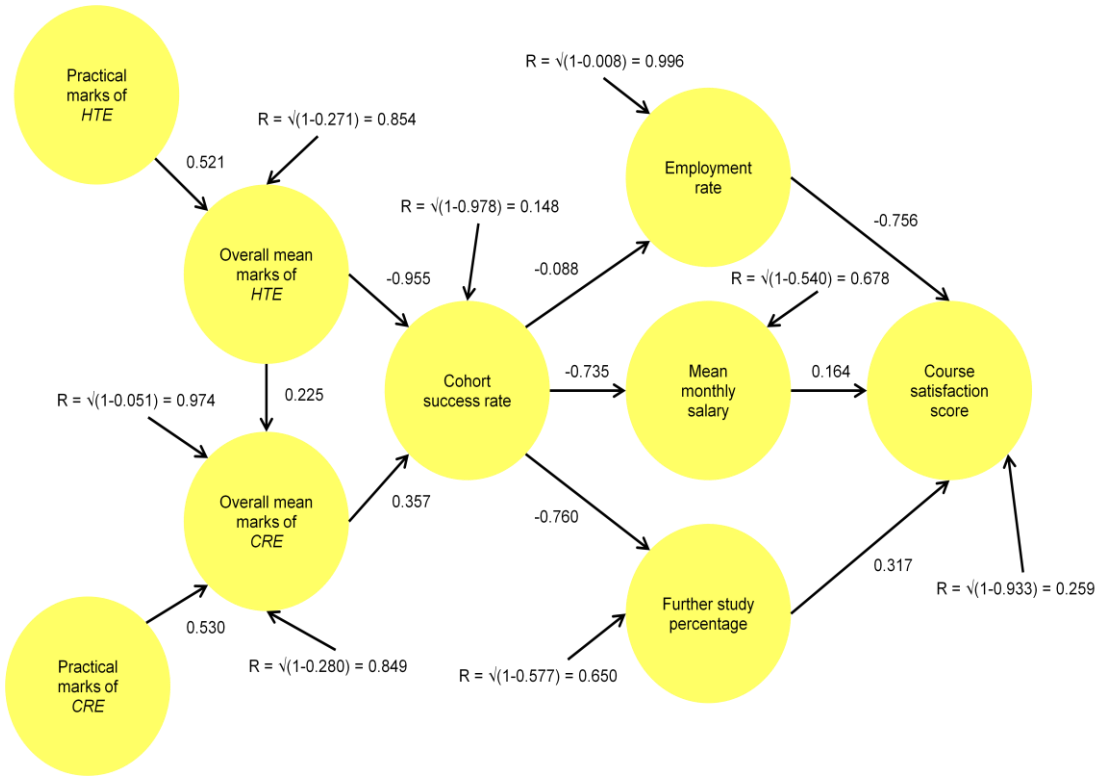

Figure 1: Path model that shows the correlations between student performance, graduate performance and course performance before CDIO implementation in DCHE.

CONCLUSION

Based on the present evaluation data, it is clear that no firm conclusions can be drawn on the effects of CDIO implementation on DCHE. This is largely due to several limitations that are present in the current evaluation study.

A primary limitation of the current evaluation study is the disparity in DCHE faculty's CDIO proficiency in adopting the CDIO education framework into their respective modules. Hence, it is recommended that prior to future evaluation studies, the DCHE Course Management Team (CMT) should work towards ensuring that the selected DCHE modules should be taught by faculty with equitable CDIO proficiency.

A second limitation is the frequent change in faculty teaching a particular DCHE module. Thus, it is recommended that the DCHE CMT should identify faculty who are most likely to remain teaching the same module consecutively for three to five years. Of course, in practice this may be impossible for obvious reasons. However, if achievable in large part, these faculty will be given ample time to fine-tune the CDIO implementation into their specific modules. This will enable DCHE to conduct a more reliable evaluation of the CDIO implementation.

Thirdly, there is only a "partial" adoption of the CDIO education framework in DCHE modules. That is to say, DCHE faculty tend to only implement CDIO in the practical component but not in the test and examination components of their modules. As such, it is also recommended that the DCHE CMT should review the adoption of CDIO education framework by relooking at test and examination components of DCHE modules. For instance, weightages of test and examination components can be adjusted lower, and types of test and examination questions can be more application-based rather than memory-based.

Lastly, there is a lack of post-CDIO implementation data. Therefore, it is recommended to continue collecting the relevant graduate and course performances data for the next five years before conducting the next evaluation study in the aspects of graduate and course performances.

In conclusion of this paper, while no decisive outcomes can be drawn on the effects of CDIO implementation on DCHE in the aspects of student, graduate and course performances, the current evaluation study has enabled DCHE CMT to recognise limitations in its CDIO implementation. From this basis, we are able both to improve specific aspects of our programme implementation and future evaluation activity.

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APPENDIX A – SAMPLE OF DATA COLLECTED FOR THE EVALUATION STUDY IN THE ASPECT OF STUDENT PERFORMANCE

Academic Year 2007	*HTE* Marks		*CRE* Marks		Academic Year 2007	*HTE* Marks		*CRE* Marks	
	Overall Mean	Practical	Overall Mean	Practical		Overall Mean	Practical	Overall Mean	Practical
1	58	71	67	73	21	87	82	72	86
2	72	71	78	90	22	87	82	72	85
3	67	71	83	90	23	88	82	79	86
4	72	73	50	72	24	69	77	75	85
5	75	73	81	91	25	81	66	64	68
6	65	73	86	91	26	45	66	69	81
7	76	78	78	91	27	65	66	53	75
8	88	78	71	88	28	61	77	64	77
9	76	78	72	90	29	84	77	69	75
10	87	75	70	85	30	68	77	57	77
11	69	75	68	84	31	54	80	53	69
12	44	75	58	84	32	72	80	83	74
13	58	72	55	80	33	49	76	78	73
14	66	72	74	86	34	45	76	72	73
15	81	73	80	87	35	75	76	70	77
16	85	73	83	91	36	66	76	57	74
17	47	71	70	73	37	90	79	61	82
18	41	71	56	89	38	84	79	56	73
19	82	82	70	89	39	73	79	71	86
20	57	82	55	86	40	84	79	92	89

APPENDIX B – DATA COLLECTED FOR THE EVALUATION STUDY IN THE ASPECT OF GRADUATE PERFORMANCE

Academic Year	Cohort	Employment Rate (%)	Mean Monthly Salary (SGD$)	Further Study Percentage (%)
2007	2004	94	1,951	47
2008	2005	89	2,323	52
2009	2006	80	2,279	64
2010	2007	92	2,213	71
2011	2008	96	2,317	63
2012	2009	100	2,461	74

APPENDIX C – DATA COLLECTED FOR THE EVALUATION STUDY IN THE ASPECT OF COURSEPERFORMANCE

Academic Year	Cohort	Cohort Success Rate (%)	Course Satisfaction Score (On a Scale of 1 to 5)
2007	2004	95	3.08
2008	2005	89	3.26
2009	2006	91	3.38
2010	2007	87	3.28
2011	2008	89	3.13
2012	2009	82	3.22

BIOGRAPHICAL INFORMATION

Claire Ng Huiting is the Course Manager for Diploma in Chemical Engineering in School of Chemical & Life Sciences at Singapore Polytechnic. Additionally, she is also one of the Academic Mentors in her institution. She has been actively involved in the curriculum redesign of the Diploma in Chemical Engineering by means of CDIO and Design Thinking adoption. Her current academic scholarly activities include utilisation of mobile learning devices, as well as designing of flipped classroom activities.

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