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The CDIO-based Maker Space Framework: Application with Engineering Management Students*

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Creating maker spaces is an effective approach to enhancing creativity. Maker spaces, commonly libraries, are often utilized within the science, math, technology, and engineering (STEM) field; their use has not been extensively researched in the context of engineering education. Conceive-Design-Implement-Operate (CDIO) is an already well-established engineering education technique. This paper establishes a Framework of Maker Spaces (FMS) based on CDIO for engineering management students composed of the Innovation Studio Project (ISP) I–IV. A total of 160 students participated in the experiment who were randomly assigned into two groups: Group A, given maker spaces with teacher guides, and Group B, who were taught by teachers in the form of traditional curricula. The results indicate that maker spaces have a positive impact on student performance, especially team innovation and individual innovation indicators. Group A students also reported higher satisfaction than Group B. This study marks the first CDIO-based maker space framework applied to the ISP I–IV for engineering management students. The results presented here may represent workable guidelines for further research on maker spaces.

Keywords: maker spaces; engineering education; CDIO; syllabus

1. Introduction

Rapid and extensive economic innovations have brought about dramatic changes within the construction industry, which in turn have inextricably altered the employment environment for engineering management graduates [1]. As the construction industry industrializes, new construction projects grow increasingly larger and more complex. Construction projects are no longer limited to traditional residential homes, factories, roads and bridges, but also include high-rise buildings, prefabricated buildings, commercial multifunctional buildings, airports, metro systems, high speed railways, and nuclear power stations [2]. Engineering teams must have keen innovation and cooperation skills to effectively execute such large-scale, complex, and difficult-to-manage projects. To successfully complete projects and maintain the continuous development of various enterprises, the construction industry needs individuals capable of deftly solving extremely difficult problems [3]. Traditional engineering education curricula center on natural sciences (e.g., mathematics and physics) and civil engineering technology, which do not satisfy the needs of the changing market.

The industrialization of construction industry and other market innovations have, in short, created new requirements for engineering management students. Graduates must have traditional project management and construction cost estimation abilities, but they also need to be creative, innovative, and able to swiftly adapt to new technologies [4]. They also must possess the teamwork competence necessary to efficiently and effectively manage highly complex projects [5, 6].

As engineers are faced with increasingly difficult and complex problems, it is urgent to cultivate current students' innovative and creative abilities [7–9]. Creativity is a skill student need to address problem-solving, divergent thinking, and product innovation obstacles in their careers. Most engineering students do consider creativity an indispensable skill; they are often willing to take courses specifically designed to enhance creativity [10]. Although engineering students are interested in creativity, arguably, existing curricula do not satisfy this demand. Universities tend to focus on basic and applied knowledge, skills, and abilities, while creativity is trained based on extracurricular (or non-major-related) activities [11]. Courses also tend to be delivered under traditional teaching modalities that center on teachers, which is disadvantageous in terms of student creativity [12–16]. Engineering education must prepare students to be active, innovative, creative, and adventurous if they are to succeed in the field. In response to current trends, recent reforms have introduced maker spaces to the engineering education environment alongside curriculum reform [1, 14, 15].

Maker spaces allow peers to come together to create and share resources and knowledge. They

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promote learning through play; they have the potential to "demystify" STEM concepts [17]. Maker spaces allow helpful practice with various materials and concepts while enhancing the makers' problem-solving and creativity skills [18]. Because maker spaces center on creativity, they are typically considered a component of extracurricular activity or academic competition rather than curriculum. Generally speaking, professional education is separate from the maker space. They are not utilized specifically to train for creativity according to market needs [19].

Modern engineering education programs are designed to impart to students with a broad base of knowledge, skills, and attitudes necessary to become successful young engineers. This array of abilities is represented in the Conceive-Design-Implement-Operate (CDIO) syllabus, which serves to create a rational, complete, consistent, and generalizable set of goals for undergraduate engineering education [20]. CDIO may thus be an ideal medium to link professional engineering education and maker spaces.

Maker spaces, when deployed properly, may promote innovation and creation in engineering students. It is yet essential to establish a framework for maker spaces to support effective engineering education and student performance. The present study was conducted in an effort to fill this knowledge gap. The main objectives were as follows:

(1) To establish a maker space framework for professional engineering education based on CDIO, which corresponds the project life cycle.
(2) To assess the impact of maker spaces on various student performance indicators including total score, team report (TR) score, team innovation (TI) score, individual report (IR) score, and individual innovation (II) score, as well as trends in ISP I–IV between maker-space students (Group A) and traditional-curriculum students (Group B).
(3) To provide a valuable reference for university educators to utilize maker spaces in engineering education.

2. Framework of Maker Spaces based on CDIO

2.1 Maker Spaces

The Makerspace Playbook defines maker spaces as "physical spaces for people, including kids, to work together and review their projects. Making can happen anywhere – on a kitchen table or in a high-end Fab Lab, a living room or a garage, a school or a community center" [21]. The modern maker space movement began to take shape in the mid-1990s, having formed unique non-profit associations focused on technology [22]. In June of 2014, the White House introduced its first Maker Faire which included several agencies as well as the Mott Afterschool Network, the U.S. Department of Education, and companies such as Intel, Autodesk, and General Electric [23]. There are various types of maker spaces that exist today. They generally share common features such as offering informal opportunities for learning, encouraging collaboration, helping to develop problem-solving and exploration skills, and helping to facilitate activities that involve creation [24–26]. The extant literature on maker spaces centers on libraries, STEM-related spaces, and K-16 education spaces; few studies have involved engineering education specifically. Creativity is a crucial skill for future engineers, and maker spaces may be an effective way to enhance creativity in engineering students [27–29].

2.2 CDIO Syllabus

With support from the Knut and Alice Wallenberg Foundation, the Royal Institute of Technology (KTH), Linköping University and Chalmers University of Technology of Sweden, and the Massachusetts Institute of Technology (MIT), the CDIO Initiative was initially launched to improve undergraduate engineering education worldwide [30]. Since then, CDIO has played an increasingly important role in curriculum design, teaching methodology, and assessment in the engineering education environment [31, 32]. Modern engineering education curricula are designed to train engineers with multi-faceted knowledge and skills according to the CDIO Syllabus [33, 34].

The CDIO Syllabus 1.0 was first published in 2001. The CDIO standard 1.0 was formed in 2004 [35]. In this vision, the first level of the CDIO Syllabus consists of four sections: Technical knowledge and reasoning, personal and professional skills and attributes, interpersonal skills (teamwork and communication), and finally, conceiving, designing, implementing, and operating systems in the enterprise and social context [20].

The CDIO Syllabus 2.0 and standards 2.0 was proposed in 2011. The first level of the CDIO Syllabus 2.0 also consists of four sections: Disciplinary knowledge and reasoning, personal and professional skills and attributes, interpersonal skills: teamwork and communication, and finally, conceiving, designing, implementing, and operating systems in the enterprise, social, and environmental context [36–39]. There are two changes in the first level of the CDIO Syllabus and eight changes in the second level of the CDIO Syllabus. Compared to CDIO Syllabus 1.0, CDIO Syllabus 2.0 has missing skills and clearer nomenclature which make it more explicit and more consistent with national standards [40].

2.3 Engineering Management Student Maker Space Framework based on CDIO

As a reference for engineering curriculum design in engineering education, most of which is professional coursework, CDIO is rarely applied to maker spaces. However, we found that maker spaces can indeed connect professional education and innovation. As CDIO is relevant to the entire life cycle of a project, the proposed course framework can be divided into several stages. We applied maker spaces in the form of an Innovation Studio Project (ISP) series course, then established the Framework of Maker Spaces (FMS) for engineering management students based on CDIO as shown in Fig. 1.

There are two main components to ISP I (conception): Conceptual planning and project planning. Similarly, ISP II (design) has two main components: BIM civil engineering deepen design (BIM CEDD) and BIM mechanical and electrical (BIM M&EDD) deepen design. ISP III (implementation) has three main components: Construction cost estimation, construction organization design, and project management. ISP IV (operation) components include property and operations management. ISP I–IV are carried out over four semesters in accordance with the CDIO modality for engineering education. The four ISPs are based on the same construction project to familiarize students with the entire life-cycle of projects.

3. Method

The research methodology of this paper included a literature review, framework construction, experimental design, experiment, and score analysis. A roadmap of this research is shown in Fig. 2.

3.1 Sample

A field quasi-experimental design was used in this study. The participants were 160 engineering management students who took ISP I–IV from the year 2015–18. The four ISPs span 16 weeks; the teamwork and individual work are completed in the seventh week. The 160 students were randomly assigned into two groups: Group A (80 students) was instructed in the form of maker spaces with teacher-guided activities, while Group B (80 students) was taught by teachers in the form of traditional curricula which is focused on teacher leadership. Each group was further divided into four-student work teams; each student was given an opportunity to lead the team at some point during the four ISPs. Both groups consisted of 20 teams at the end of the project. Students in each group were informed of the form of course and the rules applied to their own group.

3.2 Research Objective

An experiment was conducted to examine the effects of CDIO-based maker spaces on engineering management student performance. The objectives are:

(1) To compare total/TR/IR scores between Groups A and B through ISP I–IV and assess whether maker spaces have a positive impact on student performance.
(2) To compare TI/II scores between Groups A and B through ISP I–IV and explore whether maker spaces have a positive impact on innovation.
(3) To compare the self-reported satisfaction with the curriculum form between Group A and Group B students throughout ISP I–IV.

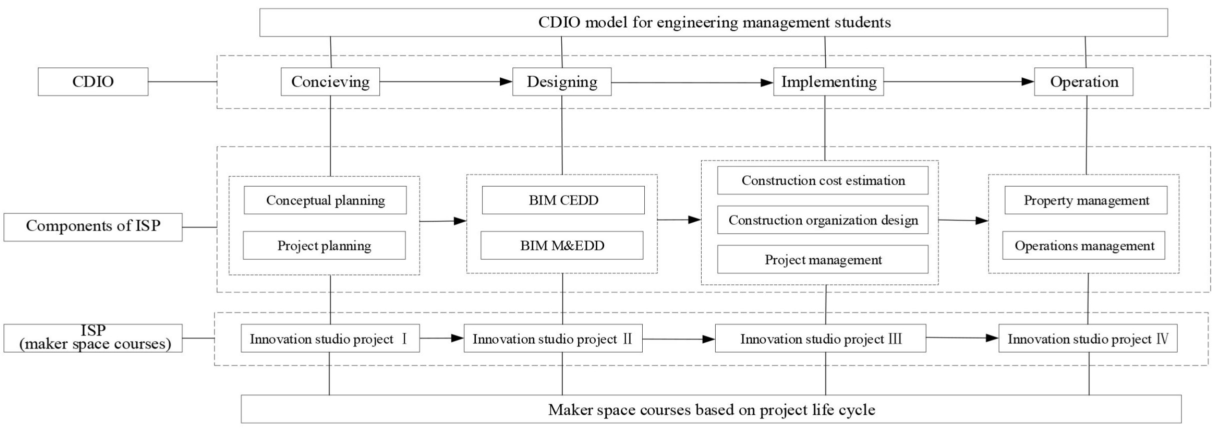

Fig. 1. Framework of maker spaces for engineering management students based on CDIO.

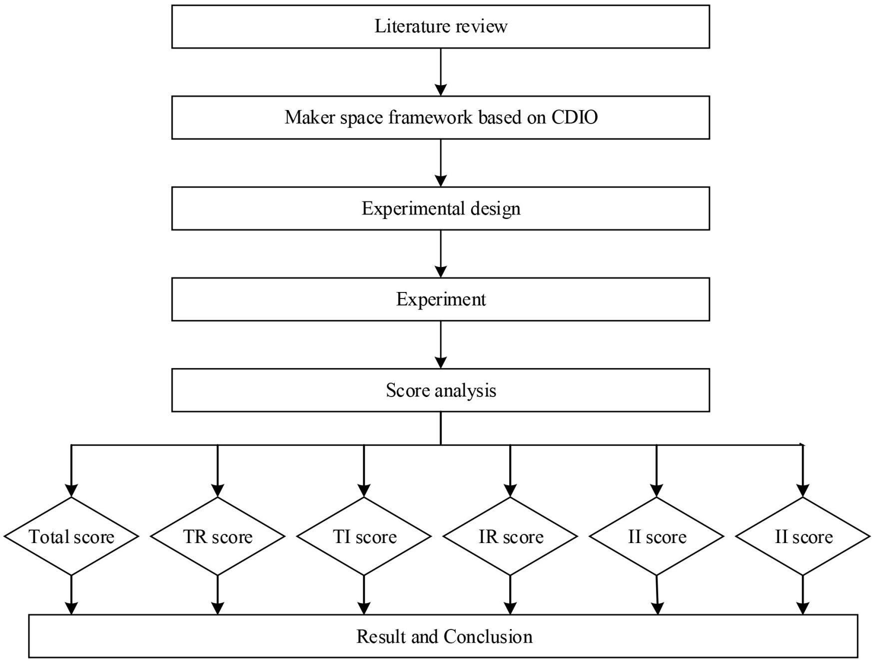

Fig. 2. The research roadmap.

Table 1. Assessment of ISP I–IV

Assessment method	Assessment content	Percentage (%)
Team report (35%)	Integrity of team report	10
	Consistency of team report	10
	Quality of team report	15
Team innovation (15%)	Team innovation in project	8
	Team innovation in problem solving	7
Individual report (35%)	Integrity of individual report	10
	Consistency of individual report	10
	Quality of individual report	15
Individual innovation (15%)	Individual innovation in project	8
	Individual innovation in problem solving	7

3.3 Assessment Design

Each of the work teams selected a project to complete over the entire four-ISP, 16-week program. Students experienced different problems throughout their project's life-cycle and studied various engineering practices in the different stages to resolve them. The ISP I–IV assessment used in this study has four parts: Team report (35%), team innovation (15%), individual report (35%), and individual innovation (15%) (Table 1).

The TR assessment includes integrity, consistency, and quality indicators which account for 10%, 10% and 15% of the total score, respectively. The TI assessment includes indicators of team innovation in the project and team innovation in problem-solving, which account for 8% and 7% of the total score, respectively. The IR assessment includes integrity, consistency, and quality indicators which account for 10%, 10%, and 15% of the total score respectively; the II assessment includes indicators of the individual innovation in the project and problem-solving, which account respectively for 8% and 7% of the total score.

There are several factors which are important to conducting an accurate assessment.

(1) In the first class given to the students, the teacher informed the students of their group, their team members, the teaching mode, and the assessment method to ensure proper instruction was given.
(2) Students were instructed to notify their teacher if any problems arose which may influence the final results.
(3) Groups A and B were instructed by the same teachers throughout ISP I–IV to ensure consistent scores. The four components (TR, TI, IR, and II) were mixed together for evaluation to avoid any effects of distinction among them.
(4) All the scores were placed on a 100-mark system (except the curriculum form assessment) encompassing the assessment content to compare TR, TI, IR, and II indicators. A score of 0–20 represents "very poor" level, 21–40 represents "poor" level, 41–60 represents "medium" level, 61–80 represents "good" level, and 81–100 represents "very good" level.
(5) In the implementation of four ISPs, each stu-

Table 2. Total score descriptive statistics of group A and group B

Course	Group	N	Minimum	Maximum	Mean	SD
ISP I	A	80	35	65	54.88	6.66
	B	80	40	60	50.50	6.35
ISP II	A	80	42	72	60.19	7.64
	B	80	33	63	53.01	6.94
ISP III	A	80	41	75	64.20	8.44
	B	80	35	65	55.44	7.43
ISP IV	A	80	55	77	69.48	5.90
	B	80	40	70	58.13	7.61

dent of each team was given a chance to team-lead so they could be fairly assessed in terms of TR and TI.

(6) Once the ISP I–IV ended, each student was asked to evaluate the curriculum form in his or her own group on a scale from 1–10 where 1 represents "most unsatisfied" and 10 represents "most satisfied".

4. Results

4.1 Total Score

The total score descriptive statistics of Groups A and B are shown in Table 2. The average scores of ISP I–IV in Group A are 54.88, 60.19, 64.20, and 69.48; those of Group B are 50.50, 53.01, 55.44, and 58.13 [41–43]. The average total ISP I–IV scores between groups are shown in Fig. 3. It appears that the total score trends increased across the program in both groups, but the scores of Group A were consistently higher than those of Group B.

Multivariate Analysis of Variance (MANOVA) is a statistical test procedure for comparing the multivariate means of several groups [44]. The common significance test of MANOVA is Wilk's Λ, which produces scores between 0 and 1. When Wilk's Λ is smaller, the effect of the independent variable is more likely to reach the significance level. When Wilk's Λ is greater, the effect of the independent variable is less likely to be significant [45].

The MANOVA results of ISP I–IV total score between the two groups are shown in Table 3. The Wilk's Λ is 0.33, multivariate F = 78.52, $p < 0.001$, which indicates that there was at least one depen-

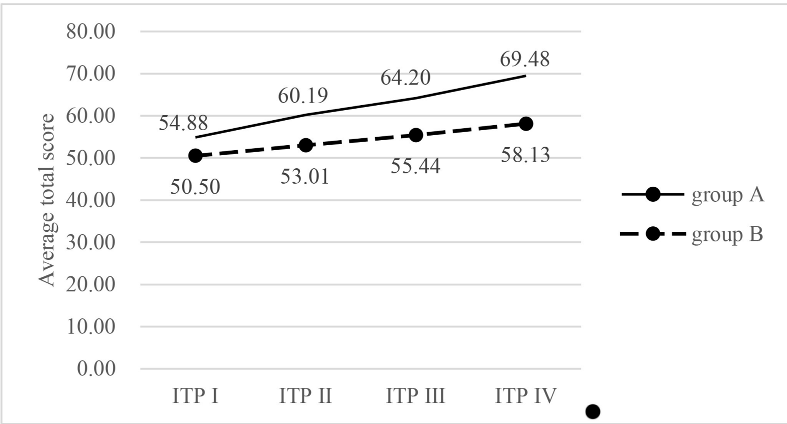

Fig. 3. Average total score of ISP I–IV between group A and B.

Table 3. MANOVA of ISP I–IV total score between group A and B

Assessment content	SS	Df	Uni-variate F	Wilk's Λ	Multivariate F
ISP I	765.63	1	18.11***	0.33	78.52***
ISP II	2059.23	1	38.65***		
ISP III	3071.26	1	48.60***		
ISP IV	5152.90	1	111.18***		

*** p < 0.001.

Table 4. TR score descriptive statistics of group A and group B

Course	Group	N	Minimum	Maximum	Mean	SD
TR I	A	20	47	75	58.85	7.64
	B	20	43	70	56.95	8.02
TR II	A	20	52	75	64.75	6.88
	B	20	43	70	58.20	7.40
TR III	A	20	46	78	66.15	8.79
	B	20	42	72	60.60	7.98
TR IV	A	20	57	78	68.90	6.04
	B	20	50	76	63.25	7.43

dent variable with a significant mean difference. Analysis of Variance (ANVOA) was conducted for further analysis. ANOVA is a collection of statistical models that allows the researcher to observe the differences between group means and their associated procedures [46]. The univariate F value of two groups in ISP I–IV are 18.11 ($p < 0.001$), 38.65 ($p < 0.001$), 48.60 ($p < 0.001$), and 111.28 ($p < 0.001$), which indicates a significant difference in total ISP I–IV score between students of different groups [47].

4.2 Team Report Score

The TR score descriptive statistics of Groups A and B are shown in Table 4. The average ISP I–IV TR scores of Group A are 58.85, 64.75, 66.15, and 68.90; those of Group B are 56.95, 58.20, 60.60, and 63.25 [47]. The average score of TR I–IV between Groups A and B is also shown in Fig. 4. It appears, again, that the TR score of both groups increase in general but that Group A consistently makes higher scores than Group B.

The MANOVA results of ISP I–IV TR scores between the two groups are shown in Table 5. The Wilk's Λ is 0.54, multivariate F = 7.55, $p < 0.001$, which indicates that there was at least one dependent variable with a significant mean difference. ANVOA was again applied for further analysis. The univariate F value of two groups in TR I–IV are 0.59 ($p > 0.05$), 8.40 ($p < 0.001$), 4.37 ($p < 0.05$), and 6.96 ($p < 0.05$), which indicates that student TR scores on ISP I do not differ significantly between the groups but that their TR scores on ISP II–IV do significantly differ [48].

4.3 Team Innovation Score

The TI score descriptive statistics of Groups A and B are shown in Table 6. Group A's average TI scores

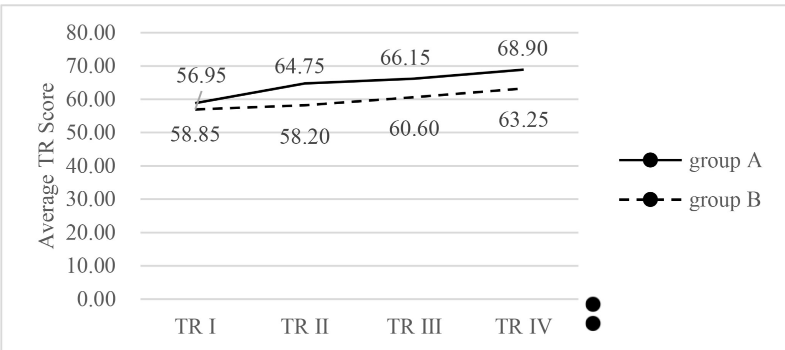

Fig. 4. Average TR score of ISP I–IV between group A and B.

Table 5. MANOVA of ISP I–IV TR score between group A and B

Assessment content	SS	Df	Uni-variate F	Wilk's Λ	Multivariate F
TR I	36.10	1	0.59 n.s.	0.54	7.55***
TR II	429.03	1	8.40***		
TR III	308.03	1	4.37*		
TR IV	319.23	1	6.96*		

n.s. $p > 0.05$, * $p < 0.05$, *** $p < 0.001$.

Table 6. TI score descriptive statistics of group A and group B

Course	Group	N	Minimum	Maximum	Mean	SD
TI I	A	20	38	55	46.35	4.87
	B	20	28	43	36.45	4.29
TI II	A	20	35	69	51.30	9.88
	B	20	28	52	41.15	7.08
TI III	A	20	44	73	61.40	8.03
	B	20	30	56	43.05	7.96
TI IV	A	20	57	80	70.40	6.23
	B	20	33	60	46.20	8.66

on ISP I–IV are 46.35, 51.30, 61.40, and 70.40; those of Group B are 36.45, 41.15, 43.05, and 46.20 [49]. The average ISP I–IV TI scores between Groups A and B are shown in Fig. 5. Similar to the other scores discussed above, the TI trends of both groups increase over the course of the program but those of Group A are consistently higher than those of Group B.

The MANOVA results of ISP I–IV TI scores between the two groups are shown in Table 7. The Wilk's Λ is 0.16, multivariate F = 47.26, $p < 0.001$, which indicates that there was at least one dependent variable with a significant mean difference. ANVOA was applied for further analysis. The univariate F values of the two groups' ISP I–IV TI scores are 46.59 ($p < 0.001$), 13.95 ($p < 0.01$), 52.66 ($p < 0.001$), and 103.03 ($p < 0.001$), which indicates that students of different groups have significant differences in their ISP I–IV TI scores [50].

4.4 Individual Report Score

The IR score descriptive statistics of Groups A and B are shown in Table 8. The average ISP I–IV IR scores of Group A are 59.21, 64.34, 64.83, and 68.69; those of Group B are 57.40, 58.74, 61.05, and 63.75 [51]. The average IR scores of ISP I–IV between Groups A and B are shown in Fig. 6. The IR trends of both groups increase on the whole, but Group A consistently makes higher scores than Group B.

The MANOVA results of ISP I–IV IR scores between the two groups are shown in Table 9. The Wilk's Λ is 0.64, multivariate F = 21.54, $p < 0.001$, which indicates that there was at least one dependent variable with a significant mean difference. ANVOA was employed for further analysis. The

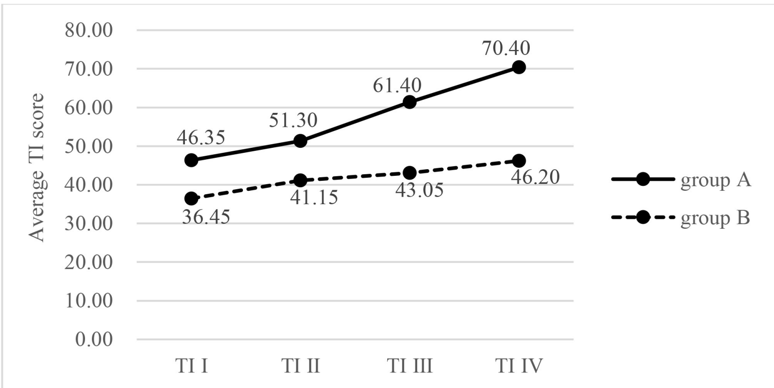

Fig. 5. Average TI score I–IV between group A and B.

Table 7. MANOVA of ISP I–IV TI score between group A and B

Assessment content	SS	Df	Uni-variate F	Wilk's Λ	Multivariate F
TI I	980.10	1	46.59***	0.16	47.26***
TI II	1030.23	1	13.95**		
TI III	3367.23	1	52.66***		
TI IV	5856.40	1	103.03***		

** $p < 0.01$, *** $p < 0.001$.

Table 8. IR score descriptive statistics of group A and group B

Course	Group	N	Minimum	Maximum	Mean	SD
IR I	A	80	46	72	59.21	7.29
	B	80	42	72	57.40	7.98
IR II	A	80	44	76	64.34	7.10
	B	80	30	72	58.74	7.72
IR III	A	80	40	77	64.83	8.38
	B	80	31	74	61.05	8.14
IR IV	A	80	53	79	58.69	5.97
	B	80	49	78	63.75	7.38

univariate F values of the two groups in ISP I–IV IR scores are 2.25 ($p > 0.05$), 22.81 ($p < 0.001$), 8.35 ($p < 0.01$), and 21.65 ($p < 0.001$), which indicates that students of different groups do not have significantly different. IR scores on ISP I but significantly different I–IV IR scores on ISP II [52].

4.5 *Individual Innovation Score*

The II score descriptive statistics of Groups A and B are shown in Table 10. The average II score of ISP I–IV of group A is 44.94, 49.81, 61.39 and 71.04, while average II score of ISP I–IV of group B is 35.55, 40.40, 43.86 and 46.95 [45].Average II score of ISP I–IV between group A and B is shown in Fig. 7. The II score trends of both group A and B increased on the whole, and the Group A scores were consistently higher than the Group B scores.

The MANOVA results of ISP I–IV II scores between the two groups are shown in Table 11. The Wilk's Λ is 0.20, multivariate F = 160.26, $p < 0.001$, which indicates that there was at least one dependent variable with a significant mean difference. ANVOA was, once more, applied for further analysis. The univariate F values of the two groups in ISP I–IV II scores are 110.28 ($p < 0.001$), 46.10 ($p < 0.001$), 175.27 ($p < 0.001$), and 386.61 ($p < 0.001$), which indicates that students made significantly different II scores on ISP I–IV [48].

4.6 *Curriculum Form Assessment Score*

The curriculum form assessment (CFA) score descriptive statistics of Groups A and B are shown in Table 12. The average CFA score of Group A is 9.11, while that of Group B is 6.53 [44]. Eta-squared

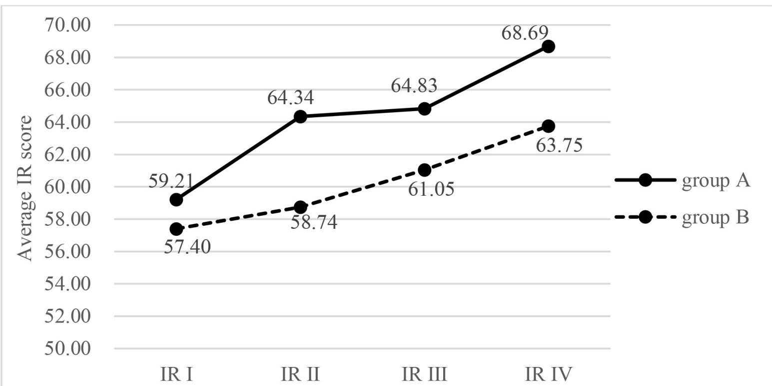

Fig. 6. Average IR score of ISP I–IV between group A and B.

Table 9. MANOVA of ISP I–IV IR score between group A and B

Assessment content	SS	Df	Uni-variate F	Wilk's Λ	Multivariate F
IR I	131.42	1	2.25 n.s.	0.64	21.54***
IR II	1254.40	1	22.81***		
IR III	570.03	1	8.35**		
IR IV	975.16	1	21.65***		

n.s. $p > 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 10. II score descriptive statistics of group A and group B

Course	Group	N	Minimum	Maximum	Mean	SD
IR I	A	80	35	55	44.94	5.47
	B	80	23	48	35.55	5.84
IR II	A	80	20	69	49.81	10.46
	B	80	20	52	40.40	6.65
IR III	A	80	30	75	61.39	9.02
	B	80	30	60	43.86	7.67
IR IV	A	80	51	83	71.04	6.75
	B	80	31	63	46.95	8.63

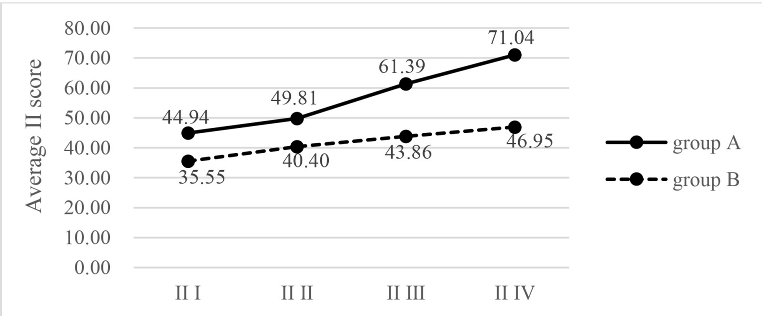

Fig. 7. Average II score of ISP I–IV between group A and B.

was used to estimate the effect size of independent variables. The eta-squared is 0.62, which indicates that different groups can explain 62% of the variations in total square deviation [52]. We conducted ANOVA to test whether different groups presented significantly different scores. The F is 291.96 and $p < 0.001$, which indicates that there is a statistic difference between CFA scores between the two groups.

5. Discussion

Our findings suggest that maker spaces indeed have a positive impact on student ISP I–IV performance; total score, TR, TI, IR, and II scores were markedly higher in Group A than Group B. The CFA scores were also better in Group A than Group B, which indicates that the FMS may lead to better performance than the traditional engineering management curriculum.

The trends of student performance on ISP I–IV are shown in Figs. 3–7. The general tendency of ISP I–IV in total score, TR score, TI score, IR score, and II score increased on the whole, as mentioned above, but with some notable differences among them. The gap between Groups A and B appears to grow wider as the ISP I–IV progresses – this is the

Table 11. MANOVA of ISP I–IV II score between group A and B

Assessment content	SS	Df	Uni-variate F	Wilk's Λ	Multivariate F
II I	3525.01	1	110.28***	0.20	160.26***
II II	3543.81	1	46.10***		
II III	12285.03	1	175.27***		
II IV	23208.31	1	386.61***		

*** $p < 0.001$.

Table 12. CFA score descriptive statistics of group A and group B

Group	N	Minimum	Maximum	Mean	SD	η^2	F
A	80	5	10	9.11	1.08	0.62	291.96***
B	80	4	8	6.53	0.98		

*** $p < 0.001$.

case for total score, TI score, and II score, and especially TI and II. This suggests that the maker space supports students as they develop innovation skills at both the team and individual level; the Group A students improved in every ISP compared to the curriculum students in Group B. However, there was no significant expansion of the gap between Groups A and B as they moved through the ISP I–IV in TR or IR scores.

The MANOVA results revealed differences between Groups A and B in total, TR, TI, IR and II scores, but again with some notable differences. The difference was significant between Groups A and B in total score, TI score, and II score – this suggests that the maker space impacts overall performance, TI, and II as the student progresses through the ISP I–IV compared to the traditional curriculum. The multivariate F of TR and IR scores also statistically significantly differed between groups, but the univariate F of ISP I showed no statistically significant difference though ISP II–IV did. This suggests that FMS has no significant impact on the TR and IR of ISP I, but does significantly affect ISP II–IV compared to the traditional curriculum.

Our results altogether suggest that the effects of the maker space are not reflected immediately in student performance, but rather over a period of time as they progress through their educational experience. The TI and II scores improved more quickly in ISP III and IV than II in Group A over Group B, which suggests that the practice the student gains in the first two ISPs helps them to succeed in the second two ISPs. We found no statistically significant difference in TR or IR between the two groups in ISP I, but a statistically significant difference between the groups' TR and IR in ISP II–IV; the FMS appears to "take effect" from ISP II onward.

Group A also made significantly higher CFA scores than Group B, which suggests that FMS students are more satisfied with their education than traditional-curriculum students. These different assessments can explain 62% of the variations in total square deviation.

The extant literature on maker spaces, as mentioned above, centers on libraries and STEM environments – there have been few previous studies focusing specifically on maker spaces in engineering education. As also discussed above, the CDIO is commonly used in engineering education. Guangjin Xiong established a design-directed curriculum based on the CDIO principles as-proposed for a civil engineering programme which places students in a broad and active design environment [34]. Tomas Svensson presented a Design-Build-Test (DBT) course in electronics which is designed based on the CDIO framework for engineering education [53]. However, few have attempted to combine maker spaces with CDIO [36–39, 54, 55], though doing so appears to markedly enhance the innovative capacity of engineering students compared to the CDIO within a traditional classroom setting. The CDIO-based FMS established in this study, as evidenced by student ISP I–IV scores, has a positive impact on student performance.

6. Conclusion

In this study, a FMS was established based on CDIO as an innovative approach to engineering management education. The proposed FMS was tested by comparison against the traditional engineering curriculum as students completed the ISP I–IV; this is the first time any research team has attempted to do so. To this effect, the results discussed above may represent a new direction for further research on FMS-related teamwork assessment.

The results of this study can be summarized as follows.

(1) Maker spaces have a positive impact on student performance; Group A (FMS) students made significantly better scores than Group B (traditional curriculum) students. The TR and IR scores of Group A were also better than those of Group B.
(2) Maker spaces have a positive impact on innovation at both the team and individual level. Students in Group A showed considerably higher TI and II scores compared to their Group B counterparts.
(3) Students reported greater satisfaction with the FMS environment than the traditional educational environment.

We applied FMS in an ISP series course in the form of maker space and traditional teaching in this study. There are some details that merit further investigation. For example, the performance assessment may be diversified. The teacher should not be the only appraiser; peer review could be included in the assessment system. Cooperation among team members is critical for effective teamwork, so team member evaluations are important aspects of the team score and individual score. Further research is necessary to improve the performance assessment by refining the evaluation method.

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