DESIGN PROCESS REPORTING TOOL FOR MAPPING AND PERFORMANCE OPTIMIZATION

[1]Fischl, G. & [1]Erlandsson, B.

[1] Jönköping University, Department of Construction Engineering and Lighting Sciences, Jönköping, Sweden

ABSTRACT

The integrative design process is becoming a fundamental part of courses offered at the Construction engineering and Lighting Sciences at Jönköping University, especially in the Architecture-engineering program. Various design processes are known, but the employed concept-test model is a good fit for the integrative design process. This study aimed to investigate how design learners' integrative design process works, and it was hypothesized that this approach fosters students' creativity. The integrative design process was separated into five tasks: Conceptualization with a mood board, Volume study, Floor-plans, Work in progress, and Poster. The quality of the design process was assessed in a Building renovation course using an online assessment platform called Design Process Reporting Tool (DIEGO). This tool measured hours spent on tasks, level of enjoyment, appraisal of the task's difficulty, perceived openness, control over the task performance, and perceived helpfulness of the peer. The results show that students suffer from performative tunnel vision and focus on the quantitative aspects rather than quality. Shortcomings in conceptual preparation and volume studies create frustration and place themselves in an uncomfortable zone. Two-thirds of the students could reach the creative zone with their peer in the process, and in the meantime control, opennes and enjoyment were experienced positively. The need to refine the conceptualization and volume study was made to unlock the full potential of the integrative design approach. Additionally, higher course grades were attainable for those individuals whose ratings on task enjoyment, effort, openness, control, and groupmate evaluation were less exaggerated.

KEYWORDS

Design process, Openness, Control, Creativity, Standards: 3, 5, 7, 8, 9, 11

INTRODUCTION

A design process can be described in many ways, and it is often reflecting the professional's own problem-solving and problem-setting approaches in a combination of personal factors, educational backgrounds, and levels of experience. In the case of a practicing professional, the vast amount of images, examples, precedents, typologies, and situations collected over the years contribute to defining a concept and testing its functionality. "*This repertoire seems to be the product of lectures, library research, site visits, precedent analysis, behavioral studies, and personal experience and preference*" (p. 50, Milburn and Brown, 2003). One of the reviewed relationships between research and design by Milburn and Brown (2003) is the concept-test model of a design process which is a good fit for an educational situation, wherein the design learners face a never-before-experienced situation, and they need to be able to develop concepts and test their functionality. The cyclical process of this development may give rise to an analytic activity enhanced with intuitive leaps when it is successful. The concept-test model can be traced back to Schön's philosophy of a reflective practice called reflection-in-action (Schön, 1983). As Visser (2010) explains, the most important character of reflection-in-action in professionals' practice (the educational situation was the primary practice of Schön at MIT) is the reflective conversations with design situations (just like in a concept-test model). The designers "*frame*" and "*reframe*" problems so that the practitioner exerts mental effort to reframe the design situation, which leads to discoveries and therefore calls for new reflection-in-action. These conversations occur in an open dialogue (usually in a design-studio situation) wherein the successful design process involves appreciation, action, and re-appreciation stages. With every framing and reframing of the design problem, the uncertain situation is more understood through the cognitive attempt of control. Furthermore, the unintended changes create new meanings that render different understanding that may contribute to the project. As Schön (1983) explains, this situation talks back to the practitioner, and if that listens and "*appreciates what he hears, he reframes the situation once again*" (Schön, 1983, p. 131-132).

For an architecture-engineering student, this dialog about framing and reframing can be frustrating since the design teacher may raise new concerns about the so-called problem setting and problem-solving. Nevertheless, the repertoire of uncertainty should not overwhelm the students but maintain a high complexity that can be accomplished in a cyclical design process constructed to encounter intuitive solutions within the course limits. This cyclical design process introduces the complexity gradually, tailoring the project complexity to the student's learning process - with the goal that the course's objectives must be fulfilled – and eventually delivering the integrative design approach.

We know about the integrated design process from the building industry's bottom-up development (Kolarevic, 2009). It started with the complex forms and surfaces with structural consequences bringing architects closer to other disciplines, which became integrated into the design process. These other professionals were still related to the building industry that used digitalization as a tool in the integration process. From integrated to integrative design process, the difference is palpable in how the disciplines work together or collaborate to achieve the goal of a building project. In terms of integrative design, the collaborating agents are creating concepts that are being tested during the design process, just like in the concept-test design model. For instance, the goal of a building project will not be merely to accommodate the families but also to reduce waste and promote healthy living with environmental performance that is no longer a burden on the city infrastructure. By elevating the conceptualization of a project to a higher level than in the integrated design, for instance, the aesthetical appeal or standard solutions are not as doctrinaire as before. In other words, the students of the integrative design process are not simply fulfilling the course requirements, the given outline for completion but achieving an individual problem-setting and problem-solving activity closely related to research by design. As Nyka, Cudzik, & Urbanowicz (2020) refers to this, "*Blurring the borders between learning and researching not only inspires students, but also fosters their creativity*" (p. 86).

Within the Concieve-Design-Implement-Operate (CDIO) community (Edström & Kolmos, 2014), the term project-based learning (PBL) curriculum is used to describe the projects as a "*platform for students to achieve competences, and to relate disciplines to each other in analysis and identification of problems as well as the problem-solving process*" (p. 541). The process skills of PBL refer to an integrated approach of self-directed learning, project management, collaboration, communication, and collaborative knowledge construction where students can reflect on their practices. By comparing PBL to the integrative design process, the difference can be highlighted in the discourse of how design learners and design practitioners communicate with each other. The integrative design approach necessitates that the design learners set the project problem-level first, which they gradually increase to a complexity that fulfills the course requirement during the discourse. In practical terms, the design learners cannot manage an integrated approach at the beginning of their design skills since their *design identity* is not yet developed, and reading the course curriculum is not prioritized when the project evolves. As Edström & Kolmos (2014) pointed out the differences between the PBL and CDIO approaches and stated that the PBL is more conductive and evidence-based; meanwhile, the CDIO approach is formal and codifiable. The integrative design process has its origin in the PBL process, in which the design learners may exceed the prescribed and pre-set goals (by CDIO standards) of the course by being able to express their creativity and design identity. The CDIO standards are valuable tools for benchmarking and curriculum development (Rosén, Hermansson, Finnveden, and Edström, 2021). The refined CDIO Standards 3.0 compared to the earlier version includes sustainability, digitalization, services, and faculty competencies (Malmqvist, Edström & Rosén, 2020). These changes align with an evolving topic on engineering education as it involves other disciplines, like social sciences and architecture.

From the perspective of architecture-engineering, the integrative design process is a pedagogical technique that was tested in a Building renovation course. This course is a design course focusing on the three different areas of renovation: reuse renovation, restoration, and conservation of an existing or historical building. The objective of the course for the students is to work on an actual building by conducting an analysis of the given building both historically and culturally and determining its reuse value, and creating a proposal for sustainable reuse architecture with a new addition to the building. The project is conceived through integrative design. This study aimed to understand how design learners' integrative design process worked. The integrative design process employed the concept-test model, and it was hypothesized that an integrative design process boosts students' perceived control and positions their learning styles to a more open preference.

METHOD

The method of investigation relied on an online design process reporting tool which included subjective assessments. Additionally, course results were added for further analysis.

Participants

Altogether, there were 59 participants out of 68 students in the second-year bachelor's program in architecture engineering. The majority were female (n=42, 71%). Participants were rewarded with two extra points in their project examination when they fulfilled the minimum of 15 data inputs (three on each of the five tasks). This way, the study rewarded 39 students with 5% of the total score on the project examination.

Data collection instruments

The Design Process Reporting Tool (DIEGO) was a quick online questionnaire that recorded items such as hours spent on tasks, level of enjoyment, appraisal of the task's difficulty, perceived openness, control over the task performance, and perceived helpfulness of the peer. The subjective assessments were recorded on a five-point Likert scale (Strongly disagree to Strongly agree), except for the enjoyment (seven-point Likert scale). Furthermore, the questionnaire included an informed consent which the participant had to accept each time and identify themselves with their email address. After reviewing the input data, n=951 reported cases were kept in the database for investigation.

Procedure

The course of Building renovation at the University of Jönköping, Department of Construction Engineering, five specific tasks were given and followed up. The students were introduced to DIEGO and the reward system during a lecture. They were asked to visit the reporting tool at least fifteen times during the group design exercise and record their answers at least three times in each design task (Conceptualization with a mood board, Volume study, Floor-plans, Work in progress, and Poster).

Task one involved an initial research stage about the given historical building and renovation project area. The students worked in a group of two and had to gather information about historical and cultural values and then write a program and put together a mood board showing the initial design concept and program requirements. The objective of task two was to follow the design process and frame and reframe the initial ideas while creating a site plan and volume study sketches for the project. This task also included a written report on historical constructions and materials. Students were required to elaborate on the concept and match the floorplans and facades in task three. These drawings had to be in scale and as presentation drawings submitted for review and criticism. The fourth task involved presenting and submitting the work in progress of specific illustration drawings and written reports, including site plans, floorplans, sections, elevations, renderings, and mood boards. All the drawings had to be in scale. A summarized architectural poster was made to communicate the students' overall and final ideas in task five.

Data Analysis

The raw input data of DIEGO responses is visualized on a time axis, showing the clusters and overlappings of the five tasks. Participants' data (including the course result) were further organized, and mean values of visits, hours spent, enjoyment, openness, perceived difficulty, control, and peer helpfulness were calculated task-wise. Parametric statistical differences and correlations were explored using SPSS 27 and MS Excel.

An individual scattergram shows the perceived openness and control in a quadrant format. This scattergram builts upon an earlier investigation by Fischl *et al.* (2018), Fischl & Wännström-Lidh (2020) and Fischl & Erlandsson (2021). The openness relates to the perception of the undefined-defined project form, while the control measures relate to the perceived control one feels over the actual task. The corresponding first quadrant is the *Comfortable zone*, wherein students perceive low control and a more defined task. This zone is adequate for external demands and external support for completing a task. The second quadrant is the *Uncomfortable zone,* and the students perceive an open task with a lack of control. This combination may result in helplessness or frustration. The third quadrant is the *Performative zone.* Students are driven, quantity oriented, and able to produce results. However, the qualitative component of the task is lacking. Finally, the fourth quadrant is called the *Creative zone* because this quadrant is well desired; it combines perceived control with preference to open tasks.

RESULTS

The study followed a group design exercise to understand how students perceive their integrative design process. On average, participants (n=59) visited 14,69 (SD=6,56) times the DIEGO tool and reported 77,69 (SD=44,95) hours for the five tasks. The distribution of task hours across the course span is shown in Figure 1. The values over 15 hours might be several days of combined working hours registered instead of a single-day activity. The task-specific hours are increasing as the design exercise gets more complex. The reported hours are the highest for the Work in progress task ($T4_N$=51; $T4_{mean}$=31,43; $T4_{SD}$=17,71) , which indicates that in the design process, this is where most of the design iterations are done. The second-highest hours are reported for the poster presentation ($T5_N$=51; $T5_{mean}$=23,3; $T5_{SD}$=16,95), and it is somewhat an interesting finding since this much attention was not supposed to be given to a task that is a compilation of the earlier results. The least hours are stated for the concept with mood board ($T1_N$=55; $T1_{mean}$=9,58; $T1_{SD}$=1,59), volume study ($T2_N$=50; $T2_{mean}$=12,02; $T2_{SD}$=6,95) and floor plans ($T3_N$=53; $T3_{mean}$=15,49; $T3_{SD}$=9,04). The performative impetus of the students may explain this finding. In the beginning, the students are unfamiliar with the integrative design process, and therefore, they do not pay much attention to a well-developed concept with the corresponding mood board. Furthermore, they do not understand the importance of a volume study, as it is often seen as an unnecessary task submission, which hinders them from focusing on the floor plans' main issue, such as functionality. This *performative tunnel vision* may be one of the main issues in our integrative design process development. By spending more task hours on understanding the qualitative aspects of a design exercise, the quantitative perspective on task accomplishment has to be rejected. The distribution of hours invested in each task is reported in Figure 2.

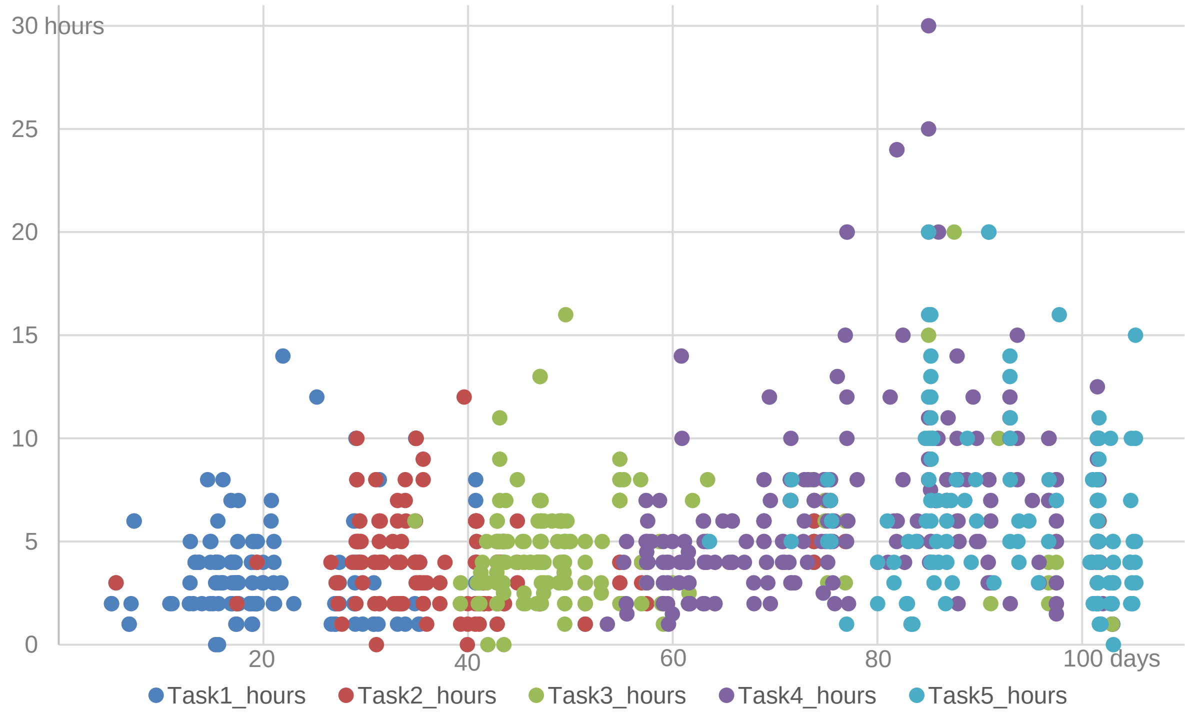

Figure 1. Scattergram of task hours reported (n=951) (Task1=Concept with moodboards, Task2=Volume study, Task3=Floor-plans, Task4=Work in progress, Task5=Poster).

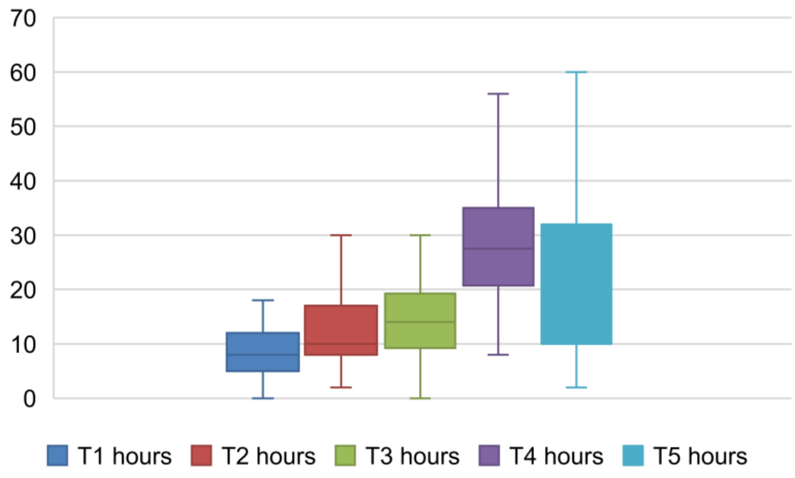

Figure 2. The minimum, maximum and the median hours reported for each task (T1=Concept with mood boards, T2=Volume study, T3=Floor-plans, T4=Work in progress, T5=Poster).

It was hypothesized that an integrative design process boost students' perceived control and positions learning styles to a more open preference. The mean values of perceived control and openness are presented for the participants in Figure 3. This shows that most of the students could find the creative zone during the group design exercises; however, one-third (n=17) of the student group failed to position themselves clearly in this zone.

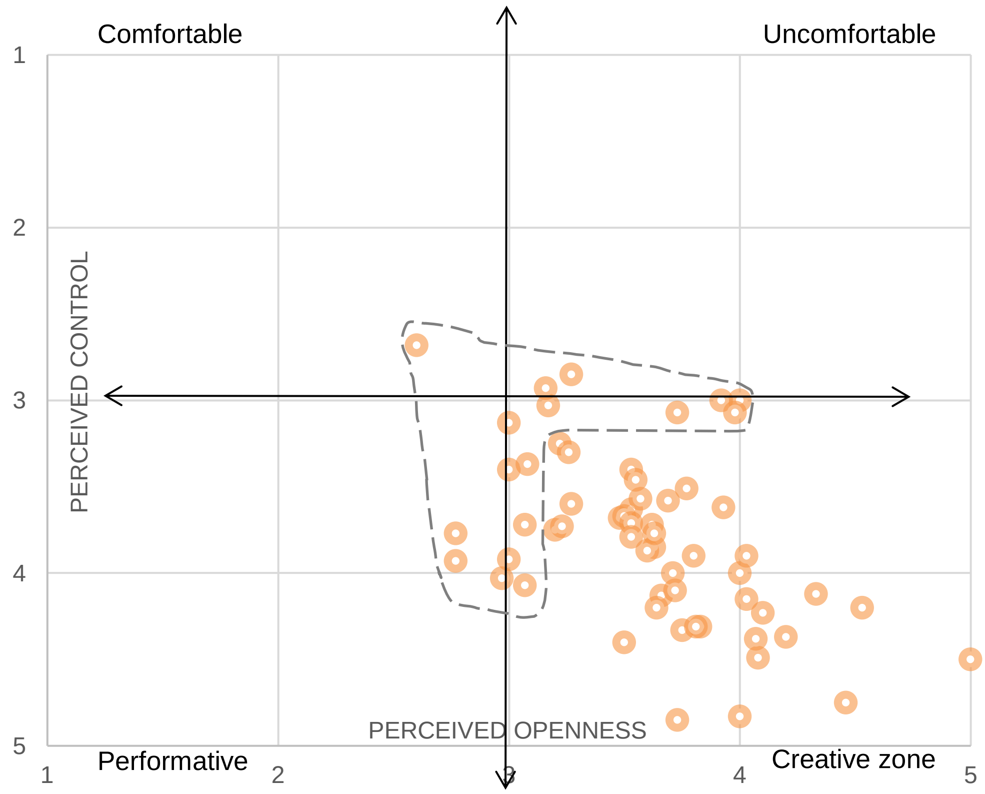

Figure 3. The participants' individual scattergram (n=59) on the perceived openness and control concerning the overall mean task performances. Note: The openness and control neutral position is located at the mean level of 3 (Control>3 more internal, control<3 more external). The project definition axis is at a neutral position (3) due to its 5-point scale (1=More open to 5=More closed).

A closer inspection of the tasks reveals how the perceived control and openness propagates throughout the project phases (Figure 4). The clusters show variation across the quadrants and display the most dispersed image for Work in progress (T4). Meanwhile, the most concentrated position for the Creative zone was the Concept development (T1). The finding for T1 seemingly contradicts the previous explanation of performative tunnel vision. This task required the least effort ($T1_N$=52; $T1_{Mean}$=2,99 ; $T1_{SD}$=0,63) and was perceived as the most enjoyable ($T1_N$=56; $T1_{Mean}$=5,57; $T1_{SD}$=1,02). It is probably because the students had not investigated many alternative concepts and mood boards; instead, they were satisfied with the first solution. Later on, this lack of exploration resulted in task confusion for T3 (Floor-plan) and T4 (Work in progress) when the concept did not match the produced drawings.

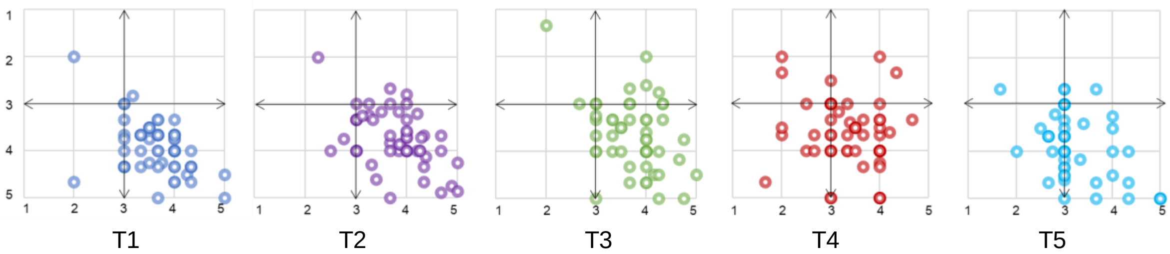

Figure 4. The variation of perceived openness and control during the different tasks (N=59; T1=Concept with mood boards, T2=Volume study, T3=Floor-plans, T4=Work in progress, T5=Poster). Note: The openness and control neutral position is located at the mean level of 3 (Control>3 more internal, control<3 more external). The project definition axis is at a neutral position (3), due to its 5-point scale (1=More open to 5=More closed).

Pearson correlation was performed between enjoyment, effort, openness, control, and groupmate ratings. The most correlation was found for groupmate rating, suggesting that satisfaction with a well-performing peer has a moderate positive correlation to task enjoyment (r(57)=.45; p<.001), and slightly negatively correlation to effort (r(57)=-.32; p<.05) exerted. In terms of openness (r(57)=.35; p<.05) and perceived control (r(57)=.34; p<.05), groupmates were slightly positively correlated. Thus, the more open and controllable the task seemed, the higher the groupmate's rating was. It was also found that as the perception of control increased, the tasks were seen as more open (r(57)=.50; p<.001) and enjoyable (r(57)=.30; p<.05).

Finally, the different course grading levels are described by the mean values of the subjective assessments, the reported hours spent on the project, and the number of visits to account for these data (Table 1). The frequencies of the higher grades (4 or 5) indicate a successful course accomplishment, and only a minority could not pass the course. Interestingly, higher values for the number of visits, hours spent on the project, and the perceived level of enjoyment, effort, and openness were reported among those who failed. These values tend to decrease as higher grades are achieved, strengthening the assumption that getting a good grade in a design project cannot be obtained by overestimating one's effort, enjoyment, and openness of the project. On the contrary, these students struggled to retain control over the project complexities and appreciate their groupmates.

Table 1. Descriptive statistics of the final grades and the mean values of the number of visits and hours spent on the project, as well as the reported subjective assessments (Enjoyment, Effort, Openness, Control, and Groupmate evaluation)

	Failed	3	4	5
N	4	7	13	35
Visits	16,75	15,14	14,38	14,49
Hours	124,50	84,43	76,73	71,34
Enjoyment	5,84	5,16	5,24	5,17
Effort	3,91	3,35	3,52	3,29
Openness	3,82	3,60	3,62	3,58
Control	3,67	3,69	3,72	3,86
Groupmate	3,89	4,32	4,54	4,49

Note: The subjective assessments are rated on a 5-point Likert scale (1=Strongly disagree, 5=Strongly agree), except for Enjoyment (1=Not at all, 7=Very much). The mean values are presented for the number of occasions (Visits) for reporting data and invested Hours in the project.

DISCUSSION

This study used the Design Process Reporting Tool (DIEGO) for collecting relevant information about the subjective appraisal of personal control and perceived project openness. The study aimed to understand how design learners' integrative design process worked.

An integrative design process as a pedagogical approach to project-based learning was introduced to the Building renovation course. The main distinction between integrated and integrative design approaches is how the disciplines work together to achieve the goal of a building project. By linking the integrative design process to the concept-test design model that has an origin in the reflection-in-action practice, using framing and reframing discourse between the design learners and the practitioners, the cyclical design process is promoted. Interpretation of the results for task distributions on the timeline shows overlaps and frequent revisits between the different tasks. Although the reflection-in-action method was new to the students, and many of them seemed not to comprehend the design practitioners' discourse at first, they slowly learned to see the freedom and creativity within the ever-increasing complexity. The students' learning process produced this complexity as they encountered design details connected to neighboring disciplines. The key to a successful design project was to develop an integrative and flexible concept for incorporating multiple objectives while being visionary. From an initial performative tunnel vision that narrowed down the design opportunities, two-thirds of the students were able to rebound. In the visualization of the control and openness quadrants, the students' positions showed when they were in a comfortable-uncomfortable, performative and creative phase. It was hypothesized that an integrative design process boosts students' perceived control and positions their learning styles to a more open preference. The hypothesis was accepted when two-thirds of the students became in the creative position of the openness-control quadrant. Further analysis could reveal each individual's journey during the course, and tailored discussion might take place for a deeper assessment. However, personalized feedback and discussions are common in the architecture discipline; it is less appreciated among architectural engineering students.

Overall, the correlations between the subjective assessments revealed that a well-performing peer is essential to the project's success. Not only because the peer supports, moderates, and is a source of project enjoyment, but because the peer helps in the reflection-in-action design process and contributes to additional discourse. The discourse-based cyclical design processes are the fundamentals of the concept-test model and for an integrative design approach. In a dysfunctional group, students report more project hours and overestimate the freedom they might possess. These can lead to a false sense of mastery of the project, being overtly positive and, in the meantime, concluding that the project cannot live up to the expectations. Consequently, the student may lose interest in the design process, start blaming the circumstances and try to find a scapegoat.

Methodologically, this study showed a promising way of encouraging students to participate in evaluating one's own design processes. The high response rate and follow-through in the administration of the questionnaire showed engagement and interest from the students. The inbuilt reward mechanism was attractive enough to maintain this behavior.

CONCLUSION

This study employed the Design Process Reporting Tool (DIEGO) to gain insight into the integrative design process. The results showed high engagement from the students and revealed the bottleneck of this integrative design process. Namely, students need to focus more on the concept building and preparatory work before starting with the floor plans because there will be more confusion and uncomfortable experiences. Gaining control and understanding of an open or undefined project would ease the performance tunnel vision that is predominantly quantitative and does not support creativity. Modifications were made during the design process to rebound from this problem. To further emphasize the concept-test model characteristics of the integrative design process, the first two tasks must be more iterative or cyclical to give rise to an analytic activity enhanced with intuitive leaps. The hypothesis that an integrative design process boosts students' perceived control and positions learning styles to a more open preference was proven true for two-thirds of the participants.

ACKNOWLEDGEMENT

The authors would like to thank the participating students for their valuable contribution to this study.

FINANCIAL SUPPORT ACKNOWLEDGEMENTS

The authors would like to thank the School of Engineering for realizing this study through the Education Supporting Research grant. The authors report no conflict of interest.

REFERENCES

Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education*, 39(5), 539-555. doi:10.1080/03043797.2014.895703

Fischl, G., Erlandsson, B. (2021). Design Exercise Strategy for Locus of Control and Self-Efficacy. *17th International CDIO Conference*, Chulalongkorn University & Rajamangala University of Technology Thanyaburi, Bangkok, Thailand, June 21-23, 2021

Fischl, G., Granath, K., Bremner, C. (2018). Mapping architectural engineering students' learning in group design exercises. Kanazawa: Kanazawa Institute of Technology, *14th International CDIO Conference*, Kanazawa Institute of Technology, Kanazawa, Japan, June 28 - July 2, 2018.

Fischl, G., Wänström Lindh, U. (2020). Change for group design exercises in a lighting design program. *16th International CDIO Conference*, Chalmers University of Technology, Gothenburg, Sweden, 9-11 June 2020.

Kolarevic, B. (2009). Towards integrative design. *International journal of architectural computing, 7*(3), 335-344.

Malmqvist, J., Edström, K. & Rosén, A. (2020). CDIO Standards 3.0 - Updates to the Core CDIO Standards. *Proceedings of the 16th International CDIO Conference*, hosted online by Chalmers University of Technology, Gothenburg, Sweden, June 8–11, 2020.

Milburn, L. A. S., & Brown, R. D. (2003). The relationship between research and design in landscape architecture. *Landscape and urban planning, 64(*1-2), 47-66.

Nyka, L., Cudzik, J., & Urbanowicz, K. (2020). The CDIO model in architectural education and research by design. *World Transactions on Engineering and Technology Education*, 18, 85-90.

Rosén, A., Hermansson, H., Finnveden, G., & Edström, K. (2021). Experiences from Applying the CDIO Standard for Sustainable Development in Institution-Wide Program Evaluations. In *17th International CDIO Conference.*

Schön, D. A. (1983). The reflective practitioner: How professionals think in action.

Visser, W. (2010). Schön: Design as a reflective practice. *Collection(2)*, 21-25. Retrieved from https://hal.inria.fr/inria-00604634

BIOGRAPHICAL INFORMATION

Géza Fischl, Ph.D. is an architect and assistant professor at Jönköping University. He is engaged in educational research in architecture-engineering and urban/indoor positioning experiments using sensors to test concepts in environmental psychology, architecture engineering, and evidence-based design. Recently, he has been combing interest in the topic of the smart built environment and the architecture-engineering design processes.

Bengt Erlandsson is currently an architect and senior lecturer at Jönköping University. He is responsible for courses where the design process is introduced and implemented into education and combines his architecture/design skills and experience with teaching. He has been working as an architect and interior architect within the various fields of commercial, hospitality, and residential design in the US and internationally. He is interested in many aspects of the design process within architecture and architectural engineering.

Corresponding author

Dr. Géza Fischl
Jönköping University,
Box 1026
551 11 Jönköping. Sweden
geza.fischl@ju.se