MAPPING ARCHITECTURAL ENGINEERING STUDENTS' LEARNING IN GROUP DESIGN EXERCISES

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ABSTRACT

Architectural engineering encompasses urban planning and architectural design exercises that are part of professional development. In contrast to the engineering discipline, the regularity of well-defined familiar tasks does not predominate in a design studio. However, to be able to work along with a larger pool of professionals and increase the potential for creative problem solving it is imperative to provide an engineering education that challenges the conventions of its framework. Consequently, students encountering design problems without prior experience need to assume responsibility for their interpretation of the problems in which they are being challenged. The aim of this pilot study was to survey, describe and analyze the problem-solving approach among undergraduate students in relation to their control strategies and successive learning. The study was completed in Jönköping, Sweden. In an online survey (N=32) using convenience sampling, students' locus of control (LOC) as the measure for control strategies over their learning situation was assessed in three school years within the undergraduate program. Additionally, three focus group interviews were performed to shed light on how individual learning modes manifested on different LOC levels and in respective school years. Descriptive statistics showed a trend that students' LOC is moving from external to be more internal by the advancement in their studies. Accordingly, they would over time develop a preference for group design exercises that are more problem-oriented, rather than assignment-based, thus matching a more internal LOC. Although the trend was clear, statistically significant differences were not found between the measured variables (LOC, gender, age, school year, subject major), possibly due to the low sample size. The focus group interviews supported the trend, where students' initial frustration over unclear instructions and dependence on external control gradually shifts toward a more reflective attitude and a greater feeling of internal control, individual competence and professional development.

KEYWORDS

locus of control, architectural-engineer, learning outcomes, problem-solving, active learning

INTRODUCTION

As the CDIO initiative (Crawley, 2001; Crawley, Malmqvist, Ostlund, & Brodeur, 2007) states, in contemporary undergraduate engineering education seems to be a conflict between the need for technical knowledge and personal and interpersonal skills that young engineers must

possess for successful team work and product realization. One of the personal traits that have been investigated over decades in diverse groups of people is the construct of the locus of control (LOC). Initially, Rotter (1954) introduced the term and referred to it as an individual's perceived control over their environment. Nowicki and Strickland (1973) elaborated upon the Rotter's LOC concept and included reinforcement as an important determinant of behavior for children's learning "appropriate social and personal behavior" (p. 148). In the process of finding appropriate behavior during a learning period, individuals must go through the problem-solving stages as Elliott, Godshall, Shrout and Witty (1990) defined in a five-stage process: general orientation, problem definition, the generating of alternatives, decision-making, and evaluation. To solve a problem, individuals must possess self-confidence and determination to achieve the goal under their control (Pretz, Naples & Sternberg, 2003), otherwise when individuals think that the solution for their problem rests outside of their control, their motivation decreases and it requires external intervention for them to succeed. Consequently, individuals with internal LOC are more effective problem solvers than individuals with external LOC (Pretz *et al.*, 2003; Konan, 2013). The internality and externality of LOC refer to the individual's orientation toward reinforcement possibilities (Çakır, 2017). When the CDIO initiative talks about problem-solving in the context of personal and professional skills, LOC can be a mediating variable for developing successful problem-solving skills in young adult students.

Architectural engineering is a field that combines engineering with the principles of design to establish functional and usable constructions. Its graduates work with a specific problem-solving approach that on one hand, originated in science-based education and on the other hand, deals with project specific open-ended problems both in planning and execution. Most architectural engineering education is a three-year bachelor's degree and encompasses urban planning and architectural design exercises as part of professional development. This problem-solving approach can then be further specified as facilitated either through an assignment, a subject project, or a problem-based learning activity (Kolmos, 1996). The underlying concept behind these categories is to focus on learning instead of teaching (Kolmos, 1996). The features of problem-based learning encompass active student participation with authentic task identification, which in turn will serve as a vehicle for future learning (Stefanou, Stolk, Prince, Chen and Lord, 2013). In this way, students determine what they need to know as well as where and how to find the critical information, hence they constantly monitor their learning and understanding of the problem. A supporting collaborative team is essential in this case for pushing and challenging each other into a deeper understanding. Teachers are at the disposal of the students to provide assistance and feedback along the learning process that builds up a culture of acquiring knowledge. In contrast to this, assignment-based learning originates in the application and integration of knowledge to a specific task in which students receive well-defined course works and time management requirements.

At Jönköping University in Sweden, the program in architectural engineering accommodates urban planning and architectural group design exercises for approximately one fourth of the total program credits (180 ECTS) in the form of compulsory and elective courses. They are an integral part of the program, together with the subjects on building physics, building materials theory, structural mechanics, structural engineering and construction technology. Within the program of architectural engineering, initiatives were taken to map and analyze students' orientation toward perceived control and its relationship to a problem-solving approach. Hence, the purpose of this pilot study became to survey, describe and analyze the problem-solving approach among undergraduate students in relation to their control strategies for successive learning in group design exercises in the architectural engineering program. To visualize the findings, the locus of control survey - intended to be used as an indicator for the control strategies - positioned the individuals or groups on the vertical axis, whereas the student's

experience of the design exercises was indicated between an assignment- and a problem-based exercise continuum on the horizontal axis.

METHOD

The pilot study employed a mix-method technique; the quantitative part included the measurement of LOC while the qualitative investigation entailed focus group interviews.

Participants

In the quantitative study part, altogether 155 students were approached for participation, including four students in the construction-engineering track, and 151 architectural engineering students. The response rate was 20,6% resulting in 32 participants (M_{age}=22.79; SD_{age}=3.219) with an evenly distributed gender profile. In terms of school year, the first-year students were 10, second-year students were 18, and the third-year students were only four. Among these students, 28 studied in the architectural engineering track, while four studied in the construction-engineering track.

The focus group interviews in each school year included four students, in total 12 (M_{age}=23.75, SD_{age}=4.45) and among them two females studied in the third year of the architectural engineering track. In terms of study tracks, two students were in the construction-engineering track in the first year, while the others studied in the architectural engineering track. For the focus group interviews, participant selection employed convenience sampling method using personal contacts within the ongoing academic courses. All twelve students participated in the LOC measures as well. Participants in the focus group interviews were rewarded with a lunch for their efforts.

Data collection instruments

An internet-based Nowicki-Strickland (1973) locus of control questionnaire was administered in the quantitative research part, in which a 40 forced-choice item is organized to measure the individuals' internal or external positions regarding their generalized control expectations. Additional measures of students' demographic data (age, gender) and their subject major were recorded together with research consent for ensuring an ethically conducted investigation.

Focus group interviews were conducted using a protocol including introduction of the topic and guidelines for interactions to ensure effective communication. The length of each interview was half an hour. A semi-structured interview was administered, and audio recorded, then transcribed. The interview questions were organized according to Kolb's (1984) experiential learning styles that incorporate four main learning modes (concrete experience, reflective observation, abstract conceptualization, and active experimentation). Questions targeted previous concrete learning experiences in group design exercises and perceived conflict and control during tasks; the questions on reflective observations entailed assignment- and problem-based exercises and issues of grading. Furthermore, students' abstract observation mode was probed by asking them to reveal how to deal with a situation that requires individuals with different skills and knowledge level, and finally a question on active experimentation mode asked how a student would use these experiences in future situations.

Procedure

Students in three architectural engineering courses responded to an email link for the Nowicki-Strickland questionnaire including inquiries on demographic data and the research consent. This questionnaire was formed in Google Forms and made available online. After agreeing to the research consent, the participants could complete the entire questionnaire online. There were three focus group interviews conducted in groups of four students and two researchers at the time, one group for each respective school year. The interviews were audio recorded, then transcribed and analyzed following the data analysis procedure.

Data Analysis

The scoring procedure of the Nowicki-Strickland questionnaire provided interval data and could be treated parametrically. The information on subject major, and gender was gathered as nominal data while age as ratio and school year as interval. The explorative data analysis employed independent t-tests, one-way ANOVA and non-parametric tests for correlation.
A content analysis of the transcribed interviews was performed using a deductive technique. The interview data was structured in three main domains. Firstly, the data was extracted to describe a position for each individual student on an assignment/problem domain, in which the perceived openness or the level of prescription of the group exercises could be located. These categories became assignment-oriented, ambivalent or problem-oriented. Secondly, the combined interviews were ranked by respondents' LOC to render the students' perspectives on learning styles irrespective of their school year. Consequently, students were categorized in internal (LOC≤6), ambivalent (LOC=7-12) and external (LOC≥13) LOC. Finally, a word frequency analysis was performed to shed light on trends of using words for expressing learning style and attitudes towards group design exercise in the respective school years.

RESULTS

The quantitative data analysis for the total sample (N=32) was intended to reveal statistically significant differences with a range of exploration on the LOC measures as dependent variables. However, the analysis did not show significant differences between LOC and subject major, school year and gender. A summary of descriptive values is presented in Table 1. The Pearson correlation showed a weak negative association between school year and LOC (r=-0,349, r^2=12%) wherein the correlation coefficient is significant at p=.050.

Table 1. Summary of LOC scores using descriptive statistics (N=32).

IV	Levels	N	M	SD
School year	1	10	12,40	3,89
	2	18	9,78	3,02
	3	4	9,00	4,16
Gender	Male	16	10,13	3,91
	Female	16	10,88	3,30
Subject major	AE	28	10,61	3,78
	CE	4	9,75	1,71

Note: IV=Independent variable, AE=Architectural engineering, CE=Construction engineering

Additional descriptive analysis was gathered for the focus group (N=12) sample. In this analysis, the individual scores on LOC were positioned and categorized according to their value on the internal-external domain (low≤6, 7<medium≤12, high≥13) as it shows in Figure 1.

In this pilot study, there were correspondences between LOC and learning styles. Learners with high LOC show preference for assignment-based learning, and vice-versa, students with low LOC show preference for problem-based learning. Over the three years, the tendency is a falling LOC, leading to a more internal control, and a tendency where preference move from assignment- to problem-based learning.

A second year external LOC (13) comment reveals that the student is moving into unchartered territory fearing unclear expectations, while the student's understanding is confronted with a new situation:

> "I think, like, from school… I had no idea that people were so different… I always thought that what I see as correct, everyone else should also see as correct… I thought it was superstrange in the beginning, sort of…what? They don't think like I do…why…?".

A third year external LOC (14) comment shows that the student is struggling to organize and find control over a more open and independent project work situation in the last semester:

> "…it's just like with the final thesis now…when you are supposed to decide everything by yourself…you just want to go and ask everyone about everything…".

Another example elaborates upon a progression of the entire school period. It should not be counted as an extreme perspective on wishes and similarities, rather a matured, reflective first year ambivalent LOC (12) student that shows awareness of the progression:

> "…that's why I feel like….more regulated in the beginning, and then open up and let the students think for themselves, the more they have studied".

The next citation from a first year ambivalent LOC (10) student shows awareness of the learning process:

> "…but I felt like that now….in the beginning it went very slowly, you wanted to understand everything, you were so careful with everything and then you were lagging behind, and then at the end when you had understood everything and just like now I do this and now I do that...but it is also hard to make it even over time...you are in a state of learning in the beginning...you are sitting trying to figure out how the software works and how you thought and you make a sketch and then you drop it and start over, and then in the end you just: Finalize everything… Bang!"

A third year ambivalent LOC (9) student comments on an issue of understanding of the scope and limitations of the project with a strong feeling of ambivalence:

> "…at the same time, I can understand this about frustration….I can feel that… that some things really should have been more clear…should it be included or not…(long pause)… so it is very different…".

The same student facing the option of having a course with an open problem:

> "…I must say, when I hear that question…undefined projects…instinctively, I feel a bit of fear…".

At the internal end of the LOC scale, a comment from a second year LOC (4) student shows a growing understanding of a future professional role:

> "I think the experience of having worked project based continuously during the education is very good when you start to work, because as I understand it, in our

> profession you work in projects where every many different actors need to cooperate and coordinate the work. It's not like hundred years ago, when an architect did the design and then the others had to solve everything else, but today everything must be coordinated in a different way. It becomes a bit like a dance, and then it is good that you have been dancing as a student."

A third year internal LOC (4) student expresses awareness of his changed attitudes towards group design exercises:

"…as they say: if you want to go fast, you go alone, if you want to go far you should go together… and to me, during the first year I found it very hard to collaborate with people, but now I have developed a much better attitude on how to approach… distribute tasks, simply collaborate…"

Figure 1 shows the relative positioning of the LOC survey results according to the students experience of the design exercises. This visual presentation in a profound way shows the development the students are taking from a highly prescriptive assignment-based experience to a less prescribed problem-based experience, while their LOC is showing a more internal orientation. First-year students are concentrated in the upper left quadrant. In the second year, there is a drop in LOC, but still more preference for assignment-based learning.

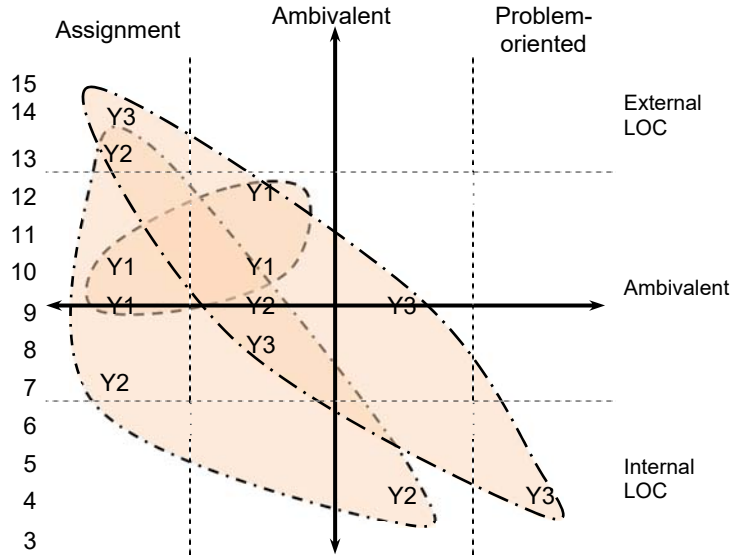

Figure 1. A summary of LOC position of each student and school year group with regards to problem-orientation. Note: Y1 means student in first year.

In the third year, the average LOC is dropping further, and preference for problem-based group design exercises have increased. The tendency shows LOC shifting from external to internal, and preferences moving from assignment- to problem-based design exercises. A section from the interview with the third-year students further illustrates this. Students are here identified by their LOC. In this excerpt, you can clearly see the competing forces between internal and external control, and the more ambivalent middle position.

LOC 4: "…no, but I prefer freedom…when you said that about problem solving, I think that is much more interesting… so absolutely, less teacher, sort of…"

LOC 8: “…it is hard to know, like, how far outside the box you may go… because you want to…you have, like in this task, things that have to be included…and then you want to include that, but how…. how much else you are allowed to do…as you say, if you are not allowed to do certain things... it is hard to know, because you want to do the task in a good way to get a good grade, you don't want to risk.... “

LOC4: “…to me it's also about taking the opportunity… for me, grades are not that important, I really don't care, I'd rather do something I believe in, and then whatever happens... “

LOC14: “…then it is just your own creativity stopping you…what may one do, what may I do…why didn't anyone tell that you were allowed to do like this…. “

LOC10: “…but at the same time, there I would perhaps never dare to take a chance “

LOC14: “…no, then you would want to discuss with your supervisor first, can you do like this, before…”

Additionally, a word frequency analysis included the 15 most frequent words in each focus group interview, whereof nine occur in all three. These words are: shall/must, do, some, then, may, think (as in have an opinion), more, also and different. The distribution of these words is shown in Table 2. For most of them, the change in ranking seems arbitrary, however some of the changes are worth highlighting.

Table 2. Word frequency count on the nine most often used words

Ranking	Frequency	1st year	Frequency	2nd year	Frequency	3rd year
1	41	shall/must	47	some	31	may
2	21	do	35	shall/must	29	think (have an opnion)
3	19	some	31	maybe	29	some
4	18	then	22	more	26	want
5	15	maybe	21	different	26	shall/must
6	15	may	19	also	25	do
7	14	think (have an opinion)	19	do	23	more
8	14	more	19	may	22	also
9	13	also	18	good	20	different
10	13	think (mental process)	17	think (have an opinion)	19	some
11	11	different	17	just	16	then

In the first year, shall/must is the most frequent word used, whereas may and think come in as number 6 and 7. In the second year, shall/must is in second place, and may and think drop down to place 8 and 10. But in the third year, may and think are propelled up to first and second place, while shall/must drops down to place 5. This indicates that first year students, in this semi-structured interview situation with identical main questions to all groups, talked significantly more about what they felt they shall or must do, and less about what could be done (as in may), or what they wanted (as in think or want). The same pattern can be found among second year students. In the third year, students talk much more about what they may do, what they want and what they think about it, and substantially less about what they shall or must do.

The actual frequency also mirror this pattern. In the first year, the top word shall/must is used almost twice as much as the next word, do (41-21 instances), whereas in the second year, the frequency difference between number one (some) and number two (shall/must) is twelve (47-35 instances). Finally, in the third year, the frequency difference between the two most used words, may and think, is just two (31-29 instances), and must/shall has dropped down to 26 instances, sharing fourth place with a completely new word, want (26 instances), further strengthening this tendency that the discourse in the third year has moved from external to a higher degree of internal control, or from being controlled to be in control.

DISCUSSION

Students in architectural engineering studies find themselves between two often-competing disciplines; engineering is generally a more prescriptive field while architecture is prone to less prescription. Students of this blend experience conflicting information during the advancement of their studies, which in turn can be the source of frustration and problems for managing interpersonal skills, project management and successful project delivery. This pilot study attempted to survey, describe and analyze the problem-solving approach of the students in relation to their control strategies to a successive learning.

The quantitative analysis had less tangible results in this study, due to the limited sample size. The descriptive statistical results on the school year LOC, however illustrated a trend toward a slowly shifting locus of control - from being external to more internal. This is in line with CDIO's suggestion about young learners' interest for feeling responsibility and ownership over their professional development. The response rate on the online survey is considered moderate, however leaving plenty of room for improvements not only in the attractiveness of the survey, but also the appropriate data collection technique.

The focus group interviews proved to be fruitful. Due to the semi-structured interview technique, a full circle of the learning style could be covered with additional probing questions. The first-year students in the focus group represent a more coherent group in terms of their LOC and problem-solving approach that locates them in the context of following instructions and satisfying the course requirements. Students belonging in this group seek to maintain a status-quo between their internal motivation and the external factors, like intended learning objectives of the design exercise in order to manage the complexity of the new situation. Meanwhile, the second-year students show a deviation from the dependent behavior that was represented in first year. Students here are more performative, exploring and utilizing their resources and motivations to excel in design exercises and occasionally finding a reason to even challenge it. Finally, students in the third year are experienced in the form of design exercises within architectural engineering. Their individual position on the problem-solving approach is more distinct compared to the first year; conversely some of them are ambivalent toward a clear preference for what extreme position they could occupy on the problem-solving approach. It is a delicate situation when a person is located in the middle range of ambivalence, because the possibility to shift oneself to a more problem-oriented approach together with an increase of externality in LOC can result in a status, wherein the feeling of being lost dominates. Conversely, the intention of a group exercise in architectural engineering would be to maintain a performative approach and, in the meantime, shift toward a creative (internal LOC and problem-oriented) phase where students can optimize their learning in design exercises. As one student mentioned it, this is like a dance and they are benefiting from it, when they are dancing as students.

CONCLUSION

The exploration of LOC and problem-solving approaches in architectural engineering group design exercises has shown a variety of results. As expected, students in the progression of the undergraduate level would prefer group exercises that move from being assignment-oriented in the beginning of the studies, to become more problem-oriented in the later years. A carefully designed education progression could also stimulate a gradual internalization of LOC, thus helping students to develop independent professional skills. The trend for this was observable, however, statistically significant differences were not found between the measured variables. The focus group interviews supported this trend, where students' initial frustration over unclear instructions and dependence on external control gradually shifts toward a more reflective attitude and a greater feeling of internal control, individual competence and professional development. A remark must be made concerning the ambivalent positions, that the risk of slipping into a higher LOC and low-prescriptive design exercise may increase the feeling of being lost. A continuous mapping of students LOC could be used as a tool to provide information when revising the educational programs and the curricula. From an educator perspective, the desired development over time would be to observe the students to develop - both as a collective and as individuals - from assignment to problem oriented and from external to internal in locus of control.

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