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THE CORRELATION BETWEEN ARCHITECTURE STUDENTS' AMBIGUITY TOLERANCE AND THEIR CREATIVITY: NEGATIVE CAPABILITY INSIDE THE DESIGN STUDIO

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Abstract. This research aims at shedding light on one of the needed skills inside the architectural design studio; that is, tolerance of ambiguity. Since design problems are characterized by complexity, unfamiliarity, and ambiguity; design process is described as a process where ambiguity is progressively resolved. Design process engenders negative feelings especially during experiencing states of not knowing and being stuck. However, most of architecture students, who are new to design process, find states of uncertainty and confusion threatening, annoying, and unnerving. Hence, the ability to navigate these negative feelings and work efficiently is important in creative design thinking. This skill is linked to a philosophical notion called negative capability; which means to have the ability to work amidst uncertainty despite the negative associations. Therefore, the researcher attempts to demonstrate the significance of negative capability, *i.e.* ambiguity tolerance, to students' design performance via revealing its influence on their creativity and design behavior. The researcher aims at exploring the relation between architecture students' attitudes towards ambiguity and their creativity via qualitative study. By recruiting 237 architecture students and assessing their ambiguity tolerance and creative thinking, the analysis revealed a significant correlation between the two variables.

Keywords: architecture students, creativity, design studio, design thinking, negative capability, tolerance of ambiguity, creativity.

Introduction

Along the design process, students face a lot of variables and unknowns in the design space. Inside the design studio, they face a distinctive type of problems; that is, design problems. These problems engender a lot of ambiguity and uncertainty. In fact, design problems are described as ill-defined since the needed information to solve it, and the way of solving it are never available for the designer (Lawson, 2005). On the other hand, the ability to handle states of ambiguity and work efficiently despite the negative impacts of such states

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is considered an individual characteristic; *i.e.*, it differs from one student to another. Architecture students who are new to the design process do not know how to handle such chaos (Litchfield, 2016).

Tolerance of ambiguity is in fact believed to contribute to the creative process as it enables individuals not to be satisfied with non-optimal solutions to complex problems (Zenasni et al., 2008). In a similar vein, the English poet John Keats introduced the term *negative capability* to describe the ability to remain capable and remain positive in negative and blurry situations. Negative capability, then, is the capacity to live with ambiguity and paradox, to remain content with half knowledge and wait until new ideas and possibilities emerge rather than rushing to the first (easy) answers. On the other hand, a conference paper argued that negative capability can be rewarding in studio environments since this capability is argued to be essential for any creative artist (Litchfield, 2016). Still, the potentials that negative capability may have to design education and students' creative thinking are untapped yet.

Hence, the main aim of this research is to highlight the significance of negative capability inside the architectural design studio. This aim will be accomplished via fulfilling the following procedural objectives:

- Exploring aspects of creative design process that are associated with ambiguity and uncertainty;
- Conceptualizing the construct of negative capability, *i.e.* ambiguity tolerance, and explore its essence and structural meaning;
- Examining the associations between students' attitudes towards ambiguity, their creative thinking, and design performance.

In order to meet these objectives, the researcher conducted a qualitative study. Our previous research has revealed the correlation between these variables; still, the sample was small (n = 18). It was also, as far as we can ascertain, the first empirical study to examine the two variables inside an architectural design studio. On the other hand, the intention in this research was to enlarge the students' sample to examine the same relation. The results corroborated the significant correlation between architecture students' abilities in living with design ambiguity and their creative thinking abilities. Accordingly, this research suggests that incorporating negative capability in design studios may improve students' creativity, and as a result, their design performance.

1. Literature review

1.1. Ambiguity in architectural design process

Design, as a mental process, has many facets. Design problems are; hence, wicked and ill-defined as they engender vagueness and ambiguity in the design space. That is why design theorists have proclaimed that design is a process where uncertainty and ambiguity are progressively resolved (Daalhuizen et al., 2009). Dealing with this dilemma is challenging for professional designers, not to mention, novice designers and design students. Recent studies have reported that during the design process designers encounter a specific pattern of psychological states (Taura & Nagai, 2011). As shown in Figure 1, at the early stages, designers experience negative states like stress, anxiety, and arousal. This may be due to the ambiguity

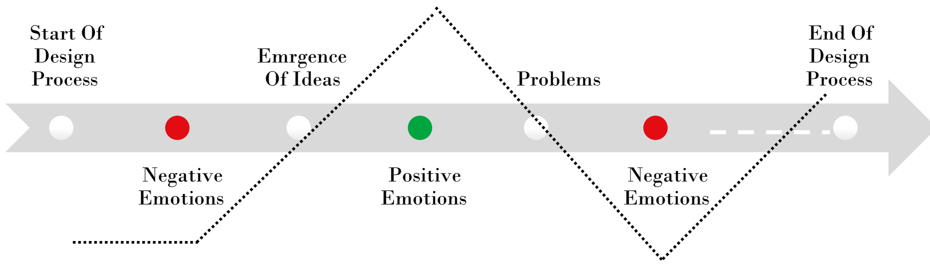


Figure 1. The pattern of psychological states in design process (source: created by authors)

of design requirements/goals and the ill-defined nature of the problem. When ideas begin to emerge, designers engage in the process and start to experience "flow". Introduced by the Hungarian-American psychologist, Csikszentmihalyi (2008), the concept of flow describes the perception of one's optimal performance due to active engagement in the task accompanied by high levels of concentration, enjoyment, and motivation. Designers alternate between flow and control while working on a defined concept or idea.

Architectural design studio, as a leaning setting, is characterized by complexity, lack of clarity, contradictory goals, and ambiguity. According to Schön (1985), architecture students face challenges when they first come to encounter the design studio; they experience language that does not resonate with their prior learning (Salama & Wilkinson, 2007). Presented with an architectural program/brief, students begin to frame the problematic situation in order to solve it. They struggle because they are expected to do what they do not yet know how to do; that is, designing. While continuing to work toward a solution, unanticipated problems that do not fit students' current understanding usually emerge. That is why most of design students feel vulnerable and defensive (Schön, 1985).

One of design aspects that needs to be communicated more explicitly to the students is navigating states of ambiguity (Ledewitz, 1985). That is why some professors believed that students must learn to work with ambiguity in order to be successful designers and architects (Cash & Kreye, 2017). Although uncertainty is usually experienced as an aversive state that need to be reduced or eliminated, students must learn to deal with the uncertainty and frustration ingrained in design processes. Thus, design education must play a role in developing students' attitudes towards ambiguity.

1.2. Creativity and design thinking

Creativity is a multifaceted phenomenon. Many attempts have been made to define creativity; still, there is no single definition that is universally accepted. Creativity refers to individuals' capacity to produce original ideas, concepts, inventions that are accepted by experts as being scientifically, aesthetically, or socially valuable. At the beginning of any creative process, problem solvers do not have a clear mental model; they need to create an appropriate model before beginning to solve the problem. A recent paper has demonstrated that resolving the ambiguity inherent in this process entails model building, problem framing, evaluating, reframing, and model testing (Schrader et al., 1993). These tasks, in fact, resonate with the definition of the design process. First, the designer develops a rough model. Then, he/she tests it to determine if it is appropriate for solving the problem at hand. If it was found to be not useful, he/she rejects it and develops another one. On the other hand, if the designer finds the developed model to be adequate, he/she refines it and pursues their work.

Uncertainty fluctuates across any process or project that deals with creating something novel. Uncertainty is always present; it never goes away or vanishes until the product or the output takes shape. Clearly, the ability to navigate this uncertainty properly is of great importance in creative problem solving; specially, in divergent thinking phase where multiple alternatives must be generated and entertained (Fields, 2011). Uncertainty or ambiguity level decreases towards the end of the creative process. However, blocks and problems that are usually encountered along the way increase this level.

According to the previous findings, design ambiguity acts in the same way. The process begins with the highest level of ambiguity and uncertainty; and accordingly, highest levels of negative psychological states. In formulating the design problem, designers try to generate an understanding in order to develop an initial configuration. When they manage to create an acceptable configuration, ambiguity decreases; which engenders more positive psychological states. This can last till a problem is discovered in this configuration, which necessitates rethinking and refining. Several iterations take place until this configuration/solution is reached. Hence, at the end of the process/project, ambiguity becomes at its lowest level, while designers' positive states become at its highest level (see Figure 2).

Therefore, there are similarities between design process and creative process. As shown in Figure 3, any creative process consists of four phases; namely, preparation, incubation, illumination, and verification (Arquero & Tejero, 2009). The problem solver understands the problem and collect the needed information to solve it, thinks and grapples with his/her first

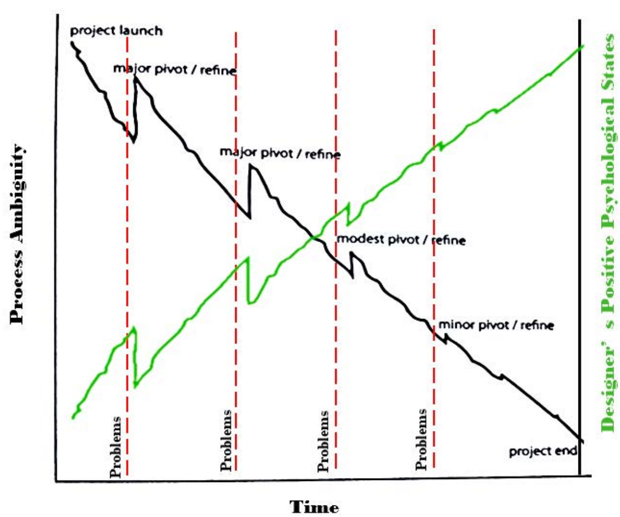


Figure 2. The dynamics of both ambiguity levels and designers' psychological states' levels across creative design process (source: created by authors)

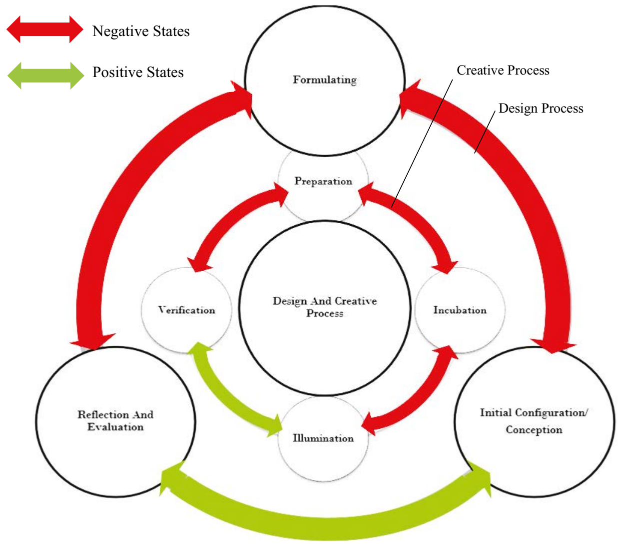


Figure 3. The matching between design process and creative process (source: created by authors)

conceptions of the solution, generates the initial configuration of this solution, and evaluates the generated mental structure/solution to verify it with respect to task requirements. As for design process, the previously mentioned model can be presented in one cycle that consists of three major phases; that is, formulating, initial configuration, and reflecting/evaluating. There is no doubt that both the two processes engender mixed emotional states along the journey to the final solution. As indicated by the colored arrows, the first part of these processes is characterized by negative emotions. Here, individuals are trying to understand all the problem aspects in order to generate an acceptable solution. However, these emotions are replaced by more positive ones once problem solvers are illuminated by a specific configuration. They experience a state of flow where they engage actively in verifying and evaluating this configuration. On the other hand, this enjoyment and concentration are replaced again by negative states when problems and blocks are encountered.

1.3. Ambiguity tolerance: "negative capability"

Intolerance of ambiguity was first introduced by Else Frenkel-Brunswik (1949) as an emotional and perceptual personality variable relevant to social orientation. Intolerance of ambiguity is the tendency to perceive vague, incomplete, unstructured, and inconsistent information as potential sources of psychological discomfort and threat (Merrotsy, 2013). As for "tolerance", the authors defined it as the process of experiencing something without being harmed (Hillen et al., 2017). Hence, ambiguity tolerance refers to the ability to withstand the chaos and fluctuations associated with solving the unclear, undefined, and ambiguous problems. According to Budner (1962), who is one of the most influential researchers in the history of tolerance of ambiguity concept, there are three characteristics of ambiguous stimuli: complexity, novelty, and insolubility. These characteristics can be found in most of design activities. Complexity implies that the designer must link a lot of information to be able to understand the situation/problem. Furthermore, designers usually work on new and unfamiliar projects, which resemble the novelty factor. Even if the project is familiar, the way its parts are combined or behave together may be unfamiliar. As for insolubility, most of design activities present conflicts and contradictions in information that designers must comprehend to pursue their work.

Several researchers have attributed tolerance of ambiguity to creative personality. Stein (1953) first introduced the concept of ambiguity tolerance to creativity literature. Moreover, one of the studies demonstrated that tolerance of ambiguity was associated with ideational fluency in brainstorming sessions. The researcher asked the participants to brainstorm for a certain task and measured their ambiguity tolerance. It was found that tolerance of ambiguity was positively linked to the number of produced ideas. Another paper aimed at examining the relation between students' ambiguity tolerance and their performance in divergent thinking tasks. 350 students participated from social studies major at a university in Western United States. Data analysis revealed that students with high ambiguity tolerance performed better in divergent tasks than convergent tasks. In contrast, students with low ambiguity tolerance excelled in convergent thinking more than divergent thinking (Brophy, 2001). Furthermore, a more recent research emphasized the correlation between creativity and ambiguity tolerance of 100 fashion design students from ten universities (Robinson, 2019).

Therefore, the previous review confirms the necessity of tolerance of ambiguity in design learning process. The capacity to continue working efficiently while dealing with such negative states is also called negative capability. In her book, *Keats and Negative Capability*, Ou (2009) linked the notion of negative capability to tolerance of ambiguity. Several books and researches have traced ambiguity tolerance concept back to negative capability (Ablon et al., 2015; Simpson et al., 2002; Ou, 2009; Küpers & Gunnlaugson, 2017; Yerushalmi, 2019). Introduced in the field of English literature, this capability refers to containment of the negative emotions that emerge from encountering ambiguity; which can enable individuals to pursue their work more creatively.

The term *negative capability* was first introduced by the English poet Keats in 1818. Keats (1818) introduced this notion in a letter he wrote to his brothers:

> "what quality went to form a Man of Achievement especially in Literature and which Shakespeare possessed so enormously – I mean Negative Capability, that is, when a man is capable of being in uncertainties, mysteries, doubts, without any irritable reaching after fact and reason".

He introduced this term as a quality of a creative artist; in this case, it was Shakespeare (Ou, 2009). The negativity of this capability does not imply deficiency, rather it implicates the ability to take in the negative emotions evoked by uncertain and ambiguous situations on behalf of the efficiency of the whole system (Simpson et al., 2002). Worth mentioning, negative capability is a form of theoretical knowledge; in contrast, tolerance of ambiguity is more related to practical application. As a capability to work effectively amidst negative emotions, negative capability is not a measurable concept, that is, there are no developed tools to assess its value in individuals. On the other hand, ambiguity tolerance can be measured and assessed; thus, a great line of empirical research has targeted examining its implications (Leggett, 2011). Hence, negative capability can be described as a construct while ambiguity tolerance can be considered a variable.

2. Study of methodology

This research aims at both; exploring the concept of negative capability with respect to design thinking, and examining the value of this capability in architecture design education. Hence, this empirical study will investigate the relationship between design students' ambiguity tolerance, creativity, and design performance via administering questionnaires to a group of architectural design students measuring their attitudes towards ambiguity and their creative thinking. In order to achieve this, an exploratory qualitative study is conducted at a well-known architecture school.

2.1. The participants

This study was conducted three years after our first research (Mahmoud et al., 2020) where a larger group of first and second year students were subjected to the selected questionnaires. They were 118 students in first year and 137 students in second year. For first year, there were 85 girls and 33 boys, while for second year, there were 92 girls and 45 boys. After receiving the questionnaires, some of the students forgot to write their names, others did not complete the Tolerance of Ambiguity Test (TAT); thus, their tests were eliminated. The final sample size for first year is 106 students; and for second year is 131 students.

2.2. Variables and measures

This section presents the used measures in order to examine the relation between students' ambiguity tolerance and creativity.

2.3. Creativity

The researcher decided to use another well-known test for assessing students' creativity. In the former study Torrance Test of Creative Thinking (TTCT) was implemented. Here, Guilford's Alternate Uses, *i.e.* the Alternate Uses Task (AUT) will be used. This test was chosen for two reasons; facilitating the process of data analysis since this sample is larger than the previous one, and examining the relation between study variables with another tool/measure; which if corroborated the previous findings, demonstrate the reliability of study findings. AUT was also developed by Torrance (1966); where participants are asked to generate as many as they can of alternative uses of a common object such as a brick, paperclip, or a pen. The participants are subjected to a limited time to complete this test; usually 2–3 minutes. The first step after collecting the tests is setting a code for each response with respect to the nature of the function introduced in the response. Hence, student's responses that have the same function were assigned the same code (Alhashim et al., 2020). A sample of students' responses is presented in the Appendix 1. AUT measures the following dimensions:

- Originality: which refers to rarity of the responses/codes. The response that belonged to a code that appeared less than or equal to 1% of the total responses receive two points. If the response belongs to a code that appeared more than 1% but less than or equal to 5% of the total responses, it receives one point. As for the response that belongs to a code that appeared more than 5%, it receives zero points;
- Flexibility: which refers to how different the responses are. It is calculated by counting the number of distinct codes assigned to student's responses;
- Fluency: which refers to number of generated responses. It is calculated by counting the number of responses presented for a specific object;
- Elaboration: which refers to the details presented in student's responses. It is calculated by assigning one point for each meaningful word included in the single response.

Hence, originality and flexibility are calculated based on the assigned codes; where fluency and elaboration are calculated based on the raw responses. The net score for each student includes: the total points of originality for each code/response, the total number of the codes associated with his/her responses (flexibility), the total number of raw responses (fluency), and the total points assigned for each raw response regarding its elaboration (Alhashim et al., 2020). The researcher selected a different object for each year; that is, first year students were asked to list the alternative uses of a paperclip, while second year students were asked to list the alternative uses of a newspaper.

However, TTCT and AUT cannot be relied on to assess the creativity of a designed product. These tests assess participants' divergent thinking; however, convergent thinking is vital in reaching successful solutions in architectural design process (Yoon & D'Souza, 2010). Since the traditional way to evaluate the creativity of students' projects is based on the agreement among the evaluators, the researcher selected the final grades of students' projects of academic year 2020–2021 (second semester) along with the previous tests to assess their creativity.

2.4. Tolerance of ambiguity

Many tests have been developed to assess ambiguity tolerance (Arquero & Tejero, 2009). Recently, Herman et al. (2010) introduced a new questionnaire in 2010. The wording of this test is friendlier and more lucid. In assessing subjects' responses, each selection is translated into points; then, total points of the 12 items/sentences can be calculated. Participants with higher scores are more tolerant than their counterparts. Hence, and like the first study, the researcher chose to use this test to assess students' ambiguity tolerance.

2.5. Procedure

The researcher met the students inside the design studio for administering the two tests (TAT and AUT); each year was met in a separate day. Since AUT is time limited, it was administered first. Then, students were subjected to TAT test in order to allow them to take their time to complete it. The following table concludes the stages and measures of the empirical study (see Table 1).

Table 1. Study design (source: created by authors)

<table>
<tr><th colspan="2"></th><th>Pilot study[1]</th><th>Main study</th></tr>
<tr><td colspan="2">No. of participants</td><td>18</td><td>237</td></tr>
<tr><td rowspan="3">Variables and measures</td><td>Tolerance of ambiguity</td><td colspan="2">Based on Jeffrey L. Herman, Michael J. Stevens, Allan Bird, Mark Mendenhall, and Gary Oddou (2010) scale</td></tr>
<tr><td>Creative thinking</td><td>TTCT[2]</td><td>AUT[3]</td></tr>
<tr><td>Design performance</td><td colspan="2">Project grades</td></tr>
<tr><td colspan="2">In-depth interviews</td><td>8</td><td>–</td></tr>
</table>

Note[1]: Based on Naiera Ebrahim Mahmoud, Shaimaa Mohamed Kamel, and Tamer Samir Hamza (2020).
Note[2]: TTCT – Torrance Test of Creative Thinking.
Note[3]: AUT – Alternate Uses Task.

3. Results

3.1. Analysis of questionnaires and tests

The researcher used students' design project grades as indication for their design creativity. At the time of conducting the experiment, which was in the second term of the academic year 2020–2021, first year students had finished designing one project; that is, a folly. As for second year students, they were not assigned a design project yet. Hence, the researcher relied on their design grades of their last project. In that project, they were asked to design a futuristic residential building that can convert/shift its design through three phases along the day according to residents' needs and uses. The following table (Table 2) shows the result of correlation-bivariate test for the whole sample (n = 237) between our students' AUT scores and their design grades. Since value of significance (2-tailed) is higher than 0.05 (highlighted in green), there is no significant correlation between the two variables.

Table 2. The results of correlation-bivariate test between students' alternative uses test scores and their design project grades (source: created by authors)

<table>
<tr><th colspan="4">Correlations for the sample</th></tr>
<tr><th colspan="2"></th><th>Design project grades</th><th>Alternate Uses Task for creative thinking</th></tr>
<tr><td rowspan="3">Design project grades</td><td>Pearson correlation coefficient</td><td>1</td><td>.054</td></tr>
<tr><td>Significance (2-tailed)</td><td></td><td>.404</td></tr>
<tr><td>N</td><td>237</td><td>237</td></tr>
<tr><td rowspan="3">Alternate Uses Task for creative thinking</td><td>Pearson correlation coefficient</td><td>.054</td><td>1</td></tr>
<tr><td>Significance (2-tailed)</td><td>.404</td><td></td></tr>
<tr><td>N</td><td>237</td><td>237</td></tr>
</table>

As for the relation between students' attitudes towards ambiguity and their design grades, the analysis clarified that there is no significant correlation between the two variables. Table 3 shows the value of significance (2-tailed) which is higher than 0.05 (highlighted in green).

Table 3. The results of correlation-bivariate test between students' ambiguity tolerance scores and their design grades (source: created by authors)

Correlations for the sample			
		Tolerance of ambiguity scores	Design project grades
Tolerance of ambiguity scores	Pearson correlation coefficient	1	–.002
	Significance (2-tailed)		.979
	N	237	237
Design project grades	Pearson correlation coefficient	–.002	1
	Significance (2-tailed)	.979	
	N	237	237

As expected, the correlation that has been attained in the first study between students' attitudes towards ambiguity and creativity has been also obtained in the larger sample. As shown below, the value of significance (2-tailed) is lower than 0.05; thus, there is a statistically significant correlation between students' TAT and AUT scores (see Table 4).

Table 4. The results of correlation-bivariate test between students' ambiguity tolerance scores and alternative uses test scores (source: created by authors)

Correlations for the sample			
		Tolerance of ambiguity scores	Alternate Uses Task for creative thinking
Tolerance of ambiguity scores	Pearson correlation coefficient	1	.199
	Significance (2-tailed)		.002
	N	237	237
Alternate Uses Task for creative thinking	Pearson correlation coefficient	.199	1
	Significance (2-tailed)	.002	
	N	237	237

Note: correlation is significant at the 0.01 level (2-tailed).

Again, the researcher wanted to explore if the significant correlation between students' tolerance of ambiguity and creative thinking is evident in each year separately; thus, the analysis was conducted for each group. For first year students (n = 106), the analysis revealed a statistically significant association between Architecture students' ambiguity tolerance and creative thinking. As shown in Table 5, the value of significance (2-tailed) is lower than 0.05; thus, there is a correlation between their TAT scores and AUT scores.

Table 5. The results of correlation–bivariate test between students' ambiguity tolerance scores and alternative uses test scores (source: created by authors)

Correlations for first year students			
		Tolerance of ambiguity scores	Alternate Uses Task for creative thinking
Tolerance of ambiguity scores	Pearson correlation coefficient	1	.251
	Significance (2-tailed)		.010
	N	106	106
Alternate Uses Task for creative thinking	Pearson correlation coefficient	.251	1
	Significance (2-tailed)	.010	
	N	106	106

Note: correlation is significant at the 0.01 level (2-tailed).

As for the relation between first year students' TAT and design grades, and the relation between their AUT and design grades; it did not show a significant correlation. In addition, the analysis was conducted for second year students (n = 131) to examine the relation between the study variables. However, there was no significant correlation between any of them. The tables showing these results can be found in the Appendixes 2–3.

Discussion

One of the aims of this study was to explore the association between architecture students' attitudes towards ambiguity and their creativity. The findings indicated that there is a significant association between students' creative thinking and their tolerance of ambiguity. In other words, students' creative performance was affected by their ability to endure ambiguity and navigate design negative states. This relation was demonstrated in both of the studies. In addition, conducting the analysis on both years separately helped in revealing that tolerance of ambiguity of first year students is significantly correlated with their creative thinking. This result was not found for second year students. This may be justified by the truth that students usually change and adapt according to educational systems and learning situations they experience. In other words, skills or attitudes of design students at their first year, like creative thinking, are raw and more natural than their attitudes at their subsequent years. Hence, it can be said that their learning experiences affected their personalities, skills, and attitudes; accordingly, this may change their characteristics which in turn contributed to losing the relation between TAT and creative thinking.

The above findings indicate that architecture students' ability to think creatively depends on their ability to endure uncertainty and ambiguity. If these students are able to sustain the negative moments of the design process, and not be paralyzed and irritated by them, they will be more capable of navigating the design space with more flexibility and resilience (Zenasni et al., 2008). On the other hand, students' ambiguity tolerance found to be correlated with their creativity at the beginning of their design process, *i.e.* divergent thinking phase, but the analysis revealed that it is not correlated with their design grades; which may be due to the second part of the process, *i.e.* convergent thinking phase. The findings indicate that students' attitudes towards ambiguity can have an impact on their creative abilities at the start of the design process, but has no impact on the process outcome/end result. This finding can be rationalized by the arguments introduced in several recent studies. These studies proclaimed that young design students are less proficient in developing their design ideas; thus, they may fail in identifying the potentials a creative idea has, which can eventually result in abandoning a promising one. In fact, a recent paper discussed that sometimes the reason behind not achieving creative solutions lies in the second phase of the design process, that is, convergent thinking (Toh & Miller, 2019).

Research limitations and future work

The absence of a correlation between students' TAT scores and their design grades can be also due to the unsuitability of ambiguity tolerance measures with respect to architectural design. They need to be designed for use in design fields; that is, to be designed to assess individuals' attitudes towards ambiguity in design thinking. It might be more convenient to use an instrument, which is not developed yet, that measures the ambiguity and uncertainty related to design processes rather than the ambiguity associated with general social situations. In fact, this argument is presented in another study (Toh & Miller, 2019).

Future work can target broadening the scope of the study by examining the study variables across all the academic years which may result in interesting findings. Moreover, design educators need to consider students' negative capability in designing their educational experiences. How to develop this type of capability needs more attention. We need a theoretical model that can guide us in the process of enhancing architecture students' creative thinking abilities via working on their negative capability, *i.e.* tolerance of ambiguity. Educators need to work with their students to not only survive in this liminality, but also to engage in it and be creative in dealing with it (Osmond & Turner, 2010; Carabine, 2013; Canter, 2016).

Conclusions

This research argues that students' ambiguity tolerance can affect their creativity inside the architectural design studio. The findings revealed that students with high tolerance towards ambiguity and uncertainty have the ability to generate more creative ideas and responses. Consequently, ambiguity tolerance can be considered an imperative skill that need to be cultivated inside design studios. Therefore, if architecture students develop their negative capabilities, they will be able to work amidst states of not knowing or being stuck efficiently; without being afraid, intimidated, or paralyzed. Hence, students' attitudes towards ambiguity must be taken in consideration in architectural education.

References

Ablon, S. L., Brown, D., Khantzian, E. J., & Mack, J. E. (Eds.). (2015). *Human feelings: Explorations in affect development and meaning*. Routledge.

Alhashim, A. G., Marshall, M., Hartog, T., Jonczyk, R., Dickson, D., Hell, van J., Okudan-Kremer, G., & Siddique, Z. (2020, 22–26 June). Work in progress: Assessing creativity of alternative uses task responses: A detailed procedure. In *2020 American Society for Engineering Education Virtual Annual Conference*. ASEE Peer. https://peer.asee.org/work-in-progress-assessing-creativity-of-alternative-uses-task-responses-a-detailed-procedure

Arquero, J. L., & Tejero, C. (2009). Ambiguity tolerance levels in Spanish accounting students: A comparative study. *Revista de Contabilidad*, *12*(1), 95–115. https://doi.org/10.1016/S1138-4891(09)70003-2

Brophy, D. R. (2001). Comparing the attributes, activities, and performance of divergent, convergent, and combination thinkers. *Creativity Research Journal*, *13*(3–4), 439–455. https://doi.org/10.1207/S15326934CRJ1334_20

Budner, N. Y. S. (1962). Intolerance of ambiguity as a personality variable. *Journal of Personality*, *30*(1), 29–50. https://doi.org/10.1111/j.1467-6494.1962.tb02303.x

Canter, R. (2016). *Students' experience of challenge, difficulty and stuckness in higher education: A qualitative longitudinal study* [PhD/Doctoral Thesis, University of Exeter, United Kingdom]. https://ore.exeter.ac.uk/repository/bitstream/handle/10871/24781/CanterR.pdf?sequence=1&isAllowed=y

Carabine, J. (2013). Creativity, art and learning: A psycho-social exploration of uncertainty. *The International Journal of Art and Design Education*, *32*(1), 33–43. https://doi.org/10.1111/j.1476-8070.2013.01745.x

Cash, Ph., & Kreye, M. (2017). Uncertainty Driven Action (UDA) model: A foundation for unifying perspectives on design activity. *Design Science: An International Journal*, 3. https://doi.org/10.1017/dsj.2017.28

Csikszentmihalyi, M. (2008). *Flow: The psychology of optimal experience*. Harper Perennial/Modern Classics.

Daalhuizen, J., Badke-Schaub, P., & Batill, S. M. (2009, 24–27 August). Dealing with uncertainty in design practice: Issues for designer-centered methodology. In *International Conferences on Engineering Design. DS 58-9: Proceedings of International Conference on Engineering Design 09* (Vol. 9, pp. 147–158). N. Bergendahl, M. Grimheden, L. Leifer, P. Skogstad, & U. Lindemann (Eds.). Palo Alto, California, United States. The Design Society.

Fields, J. (2011). *Uncertainty: Turning fear and doubt into fuel for brilliance*. Portfolio/Penguin.

Herman, J. L., Stevens, M. J., Bird, A., Mendenhall, M., & Oddou, G. (2010). The tolerance for ambiguity scale: Towards a more refined measure for international management research. *International Journal of Intercultural Relations*, *34*(1), 58–65. https://doi.org/10.1016/j.ijintrel.2009.09.004

Frenkel-Brunswik, E. (1949). Intolerance of ambiguity as an emotional and perceptual personality variable. *Journal of Personality*, *18*(1), 108–143. https://doi.org/10.1111/j.1467-6494.1949.tb01236.x

Hillen, M. A., Gutheil, C. M., Strout, T. D., Smets, E. M. A., & Han, P. K. J. (2017). Tolerance of uncertainty: Conceptual analysis, integrative model, and implications for healthcare. *Social Science and Medicine*, *180*, 62–75. https://doi.org/10.1016/j.socscimed.2017.03.024

Keats, J. (1818). *A letter to the brothers* [unpublished source].

Küpers, W., & Gunnlaugson, O. (Eds.). (2017). *The practical wisdom in leadership and organization series. Wisdom learning: Perspectives on wising-up business and management education*. W. Küpers & D. Pauleen (Series Eds.). Routledge. https://doi.org/10.4324/9781315547039

Lawson, B. (2005). *How designers think: The design process demystified*. Routledge. https://doi.org/10.4324/9780080454979

Ledewitz, S. (1985). Models of design in studio teaching. *Journal of Architectural Education*, *38*(2), 2–8. https://doi.org/10.1080/10464883.1985.10758354

Leggett, A. (2011). Constructs, variables, and operationalization. *Course Hero*. https://www.coursehero.com/file/43349172/7-5-constructs-variables-and-operationalizationpdf/

Litchfield, S. (2016). Negative capability in design studio. *Charette,* (4). https://works.bepress.com/sandy_litchfield/3/

Mahmoud, N. E., Kamel, Sh. M., & Hamza, T. S. (2020). The relationship between tolerance of ambiguity and creativity in architectural design studio. *Creativity Studies*, *13*(1), 179–198. https://doi.org/10.3846/cs.2020.9628

Merrotsy, P. (2013). Tolerance of ambiguity: A trait of the creative personality? *Creativity Research Journal*, *25*(2), 232–237. https://doi.org/10.1080/10400419.2013.783762

Osmond, J., & Turner, A. (2010). The threshold concept journey: From identification to application. In J. H. F. Meyer, R. Land, & C. Baillie (Eds), *Educational futures: Rethinking theory and practice. Threshold concepts and transformational learning* (pp. 347–364). Sense Publishers. https://doi.org/10.1163/9789460912078_022

Ou, L. (2009). *Continuum literary studies. Keats and negative capability*. Continuum International Publishing Group.

Robinson, J. J. (2019). *Mindfulness, tolerance of ambiguity, and attitudes toward interracial relationships* [PhD/Doctoral Thesis, Alliant International University, United States]. https://www.proquest.com/openview/cea0e511e59c14b2756fa353faac720a/1?pq-origsite=gscholar&cbl=18750&diss=y

Salama, A. A., & Wilkinson, N. (Eds.). (2007). *Design studio pedagogy: Horizons for the future*. The Urban International Press.

Schön, D. A. (1985). *The design studio: An exploration of its traditions and potential*. RIBA Publications for RIBA Building Industry Trust.

Schrader, S., Riggs, W. M., & Smith, R. P. (1993). Choice over uncertainty and ambiguity in technical problem solving. *Journal of Engineering and Technology Management*, *10*(1–2), 73–99. https://doi.org/10.1016/0923-4748(93)90059-R

Simpson, P., French, R., & Harvey, Ch. (2002). Leadership and negative capability. *Human Relations*, *55*(10), 1209–1226. https://doi.org/10.1177/a028081

Stein, M. I. (1953). Creativity and culture. *The Journal of Psychology: Interdisciplinary and Applied*, *36*(2), 311–322. https://doi.org/10.1080/00223980.1953.9712897

Taura, T., & Nagai, Y. (Eds.). (2011). *Design creativity 2010*. Springer-Verlag London Limited. https://doi.org/10.1007/978-0-85729-224-7

Toh, Ch., & Miller, S. R. (2019). Does the preferences for creativity scale predict engineering students' ability to generate and select creative design alternatives? *Journal of Mechanical Design*, *141*(6). https://doi.org/10.1115/1.4042154

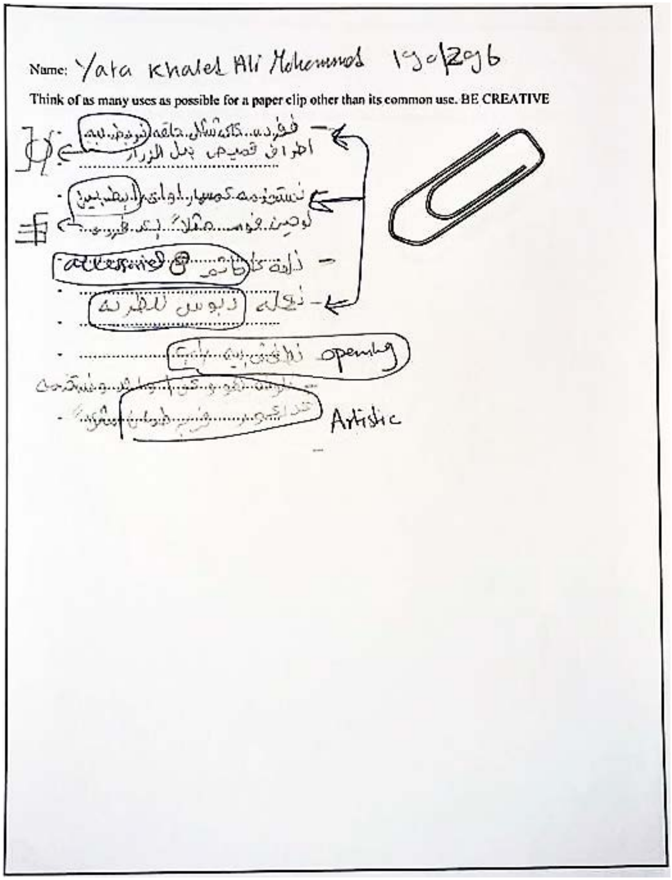
Torrance, E. P. (1966). *Torrance tests of creative thinking: Norms-technical manual. Research edition. Verbal tests, Forms A and B. Figural tests, Forms A and B.* Personnel Press.

Yerushalmi, H. (2019). Negative capability, heuristics and supervision. *British Journal of Psychotherapy*, *35*(2), 290–304. https://doi.org/10.1111/bjp.12458

Yoon, S.-Y., & D'Souza, N. (2010, 18–22, October). Different visual cognitive styles, different problem-solving styles? In *IASDR 2009 Proceedings: International Association of Societies of Design Research 2009* (pp. 2341–2352). Seoul, South Korea. International Association of Societies of Design Research Office/Korea Society of Design Science.

Zenasni, F., Besançon, M., & Lubart, T. (2008). Creativity and tolerance of ambiguity: An empirical study. *Journal of Creative Behavior*, *42*(1), 61–73. https://doi.org/10.1002/j.2162-6057.2008.tb01080.x

Appendix 1. Students' samples of alternate uses task (source: created by authors)



Appendix 2. Tables showing the correlation-bivariate test between the three variables (TAT, Alternate Uses Task and design grades) for first year students (main study) (source: created by authors)

Correlations			
		Tolerance of ambiguity scores	Design project grades
Tolerance of ambiguity scores	Pearson correlation coefficient	1	.034
	Significance (2-tailed)		.727
	N	106	106
Design project grades	Pearson correlation coefficient	.034	1
	Significance (2-tailed)	.727	
	N	106	106

End of Appendix 2

Correlations			
		Design project grades	Alternate Uses Task for creative thinking
Design project grades	Pearson correlation coefficient	1	.084
	Significance (2-tailed)		.389
	N	106	106
Alternate Uses Task for creative thinking	Pearson correlation coefficient	.084	1
	Significance (2-tailed)	.389	
	N	106	106

Appendix 3. Tables showing the correlation-bivariate test between the three variables (Tolerance of Ambiguity Test, Alternate Uses Task and design grades) for second year students (main study) (source: created by authors)

Correlations			
		Tolerance of ambiguity scores	Alternate Uses Task for creative thinking
Tolerance of ambiguity scores	Pearson correlation coefficient	1	.157
	Significance (2-tailed)		.074
	N	131	131
Alternate Uses Task for creative thinking	Pearson correlation coefficient	.157	1
	Significance (2-tailed)	.074	
	N	131	131

Correlations			
		Tolerance of ambiguity scores	Design project grades
Tolerance of ambiguity scores	Pearson correlation coefficient	1	–.011
	Significance (2-tailed)		.902
	N	131	131
Design Project Grades	Pearson correlation coefficient	–.011	1
	Significance (2-tailed)	.902	
	N	131	131

End of Appendix 3

Correlations			
		Design project grades	Alternate Uses Task for creative thinking
Design Project Grades	Pearson correlation coefficient	1	.017
	Significance (2-tailed)		.847
	N	131	131
Alternate Uses Task for creative thinking	Pearson correlation coefficient	.017	1
	Significance (2-tailed)	.847	
	N	131	131