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ADVANCING CONSTRUCTION STUDENTS' SUSTAINABILITY COMPETENCIES USING ONLINE TOOLS

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Abstract: Sustainability is an important component of engineering design and construction, however, research has shown that engineering education remains inefficient in teaching students basic principles of sustainable development. This research documents one year of using online tools to promote learning of sustainability principles in construction education. Autodesk's Building Performance Analysis (BPA) online modules were assigned in a sustainable construction class. Over the course of a semester, students were required to complete tutorials and earn the BPA Certificate. Student feedback and assessments were collected after each module was assigned, as well as after final group presentations. Overall, students concurred that the modules enhanced their learning experience both in regard to specific course material and sustainability. Findings suggest that the online training material enhanced sustainable competencies in both systems thinking and change-agents skills. Findings also suggest, however, that field trips may provide more time efficient learning enhancements. As a control, opinions regarding the effectiveness of BPA training and delivery were compared to students' who completed another online training to earn Procore's Fundamentals Certificate. Comparison suggests that Autodesk's BPA is a more effective teaching mechanism than Procore's program, but students perceive they are more likely to use Procore's project management concepts and software in industry.

1 INTRODUCTION

Sustainability is a top problem facing engineering (Vest 2006). In 2004, the Civil Engineering Body of Knowledge added sustainability as a learning outcome (ASCE 2008). Yet, research has shown that engineering education, in general, remains largely ineffective in teaching students basic principles of sustainable development (Azapagic, Perdan, and Shallcross 2005). At the same time, a current trend in higher education is increasing use of online education. In particular, the use of web-based learning is steadily increasing for traditional classrooms (Sambasivam and Li 2004). Online learning has advantages such as wide-spread availability and asynchronous delivery. Moreover, research has shown that engineers, in particular, are increasingly learning from online courses or trainings, both in school and professionally (Lawton et al. 2012).

This research primarily explores the integration of Autodesk's Building Performance Analysis Certificate (BPA) (Autodesk 2011) into a graduate level sustainable construction course, taught at the University of Colorado Denver. Autodesk describes its certificate program as an "Online Education program for building science fundamentals and Autodesk building performance analysis tools (Revit, Green Building Studio, and Flow Design)." (Autodesk 2016). Autodesk states that benefits associated with completing the program include: get job skills; learn new tools; improve designs; apply to projects; community of practice. The stand-alone program requires an email address ending with ".edu" to enroll as well as to download the supporting software. It consists of seven learning modules reported to take 25-40 hours to complete, namely: (1)

Introduction to BPA, (2) Energy Literacy and Building Loads, (3) Climate and Weather Analysis, (4) Solar Measurement and Strategies, (5) Wind and Airflow Strategies, (6) Daylighting Strategies and Analysis, and (7) Whole Building Energy Analysis.

The goal of this research is to assess the impact of integrating Autodesk's BPA Certificate program into a graduate level course focused on sustainable construction. Previously, researchers have delineated key sustainability competencies for educating sustainability to include systems thinking and an understanding of interconnectedness; long-term, foresighted thinking; stakeholder engagement and group collaboration; and action-orientation and change-agent skills (Frisk and Larson 2011). Due to the online, individual nature and the stated objectives of the BPA program, this research seeks to assess the impact of the BPA Certificate on two competencies: (1) systems thinking and understanding of interconnectedness, and (2) action-orientation and change-agent skills. In order to control for the online delivery format, the authors compare results to those from another online certificate: Procore Fundamentals (Procore 2016), as well as required class field trips. A similar student group was required to complete the Procore Fundamentals Certificate as part of a graduate level construction leadership class. The Procore Fundamentals program provides an overview of Procore's construction management software platform. It is broken into over 200 mini-learning modules or online tutorials, and is estimated to take three hours to complete.

2 BACKGROUND

Several studies have been conducted to identify the effectiveness of online and computer-based training modules in engineering education. Just-In-Time Assessment and Review (JITAR) mathematical online modules were developed to identify the effectiveness of learning different levels of mathematical abilities, from basic knowledge and skills to more advanced problems. The modules were developed using WeBWork, an online delivery software, which is an open source homework system used in over 500 colleges and high schools that supports questions and notation typically found in mathematics. The modules are designed to have content of the homework change depending on student performance. The result of the study showed positive improvements for students when they had access to online review materials as compared to previous semesters without review materials (Ozturk et al. 2015). Another study exploring online learning investigated the impact of course design on the learning outcomes. Two versions of an online course were analyzed in this study, one version used formative assessment to provide feedback to students during learning process while the other version used summative assessment. This study showed that the participants of the course that used formative assessment learned more than the other version of the course, and had more positive attitudes towards the content of the course and their future learning (Lawton et al. 2012). Vanderbilt,Northwestern,Texas,Harvard,and MIT (VaNTH) developed challenged-based instructional modules to identify the effectiveness and reliability of improving performance of students in a variety of educational settings and student populations. An associated study focused on identifying whether the improvements in the performance of the students could be achieved by instructors rather than the developers of the computer modules. The results of the study showed that challenge-based modules have moderate overall effects on improving student performance and they can be implemented successfully by instructors in a variety of student population and educational settings (Cordray, Harris, and Klein 2009). Another study was conducted to examine the implementation of games to teach undergraduate engineering students as educational games can provide motivating and stimulate environment while promoting learning by providing immediate feedback to students. This study showed that there is a general trend of improved student learning and attitudes using game-based activities (Bodnar et al. 2016). Additional related research studies focused on the effectiveness of using information technology and 3D simulation in engineering education (Kadiyala and Crynes 2000; Koh et al. 2010).

Additional research studies focused on identifying the challenges for incorporating new knowledge areas and skills into existing curriculums and the various programs that are currently offered by universities. These studies focus on technology innovation in the architecture, engineering, and Construction (AEC) industry, and included the recent trends for university curricula (Becerik-Gerber, Gerber, and Ku 2011; Johnson and Gunderson 2009); Engineering and Building Information Modeling (BIM) education and recruiting opportunities (Wu and Issa 2014; Wu and Issa 2013; Ku and Taiebat 2011); Implementing sustainability knowledge in engineering curriculum (Lynch et al. 2007; Jennings and Kachel 2015; Council 2009;

Autodesk 2015); and civil engineering body of knowledge and required skills and attitudes for the profession (ASCE 2008).

Despite the significant contribution of the existing research studies, there is limited research that focused on identifying the effectiveness of teaching sustainability to engineering students using online training modules. The primary contribution of this research study is to assess the impact of Autodesk's BPA certificate program on systems thinking and change-agents skills as sustainable competencies for students studying sustainable construction with the intent to seek jobs within the AEC industry.

3 RESEARCH APPROACH

In this research, the authors administered both paper and online surveys to students enrolled in the following graduate level construction engineering and management classes during spring 2016: Sustainable Construction and Integrated Construction Leadership. The Sustainable Construction course serves as an introduction to the major components and technologies used to create healthy, and environmentally-sensitive built environments. Content focuses on construction processes, renewable energy systems, healthy buildings, and natural and cultural resources. It explores traditional as well as cutting-edge building strategies. The Integrated Construction Leadership course focuses on various management and executive roles in AEC industries, and provides students opportunities to apply management and leadership principles in construction related case study projects.

The Sustainable Construction course content is delivered in a traditional 16 week, instructor led course and includes two on-site field trips. Throughout the course, in addition to other assignments, students were periodically assigned to independently complete each of the seven online learning modules developed and delivered by Autodesk University (Autodesk 2011). These learning modules were delivered slightly out of order from BPA's curriculum to better align with scheduled lectures throughout the semester. While a teaching assistant was available to assist with technical (i.e. computer log-in or compatibility issues) no further instruction was provided with regard to the stand-alone online modules. In contrast, the Integrated Construction Leadership course was delivered in a condensed 8-week format with a hybrid instructor-led and online activity-based format. After the first week, students were assigned to independently complete the online Procore training during a two week period. Over the following several weeks, they were also assigned team-based activities where they were required to use Procore's web-based software.

Online surveys were administered to the students either using the online course support system, Canvas, or, in the case of soliciting feedback on the individual BPA modules, google docs. When students were asked to respond using google docs, students were sent individual links so that they could not see the responses of their peers. Finally, both paper and online data were manually entered into an excel spreadsheet where the authors coded the responses and performed descriptive statistical analysis.

The convenience sample consisted of students enrolled in classes taught by the authors. Response rates for the students surveyed in both classes was 100% for the end of the semester surveys (BPA, Field trip and Procore). However, response rate for the online surveys after each BPA module throughout the semester ranged from 50-75%. A total of 16 civil engineering students were enrolled in the Sustainable Construction class consisting of: 11 males and five females; three seniors and 13 graduate students. Of the 13 graduate students, seven were members of the construction engineering and management program. By comparison, a total of five students were enrolled in the Integrated Construction Leadership class consisting of: five males (two graduate students in construction engineering and management, one graduate student in Architecture, and two non-degree seeking, industry professionals).

3.1 Description of Surveys

Four different surveys were administered over the course of the semester: post-module surveys, BPA certificate survey; Procore certificate survey; and post-field trips survey. Three of these surveys were administered in the Sustainable Construction class, and one in the Integrated Construction Leadership class. Specifically, in the Sustainable Construction class, students were asked to answer the following questions using google.docs after the completion of each online BPA module.

1. How many hours did you spend on this lesson?
2. How many different work sessions did you break this lesson into?
3. Identify two to three concepts from the lesson that overlapped with lecture material.
4. Identify two to three concepts from the lesson that are valuable for understanding sustainable design and construction.
5. How much interest do you have in the material after completing the lesson?
6. On a scale of 1 to 5, how helpful was lesson in terms of reinforcing concepts related to sustainable design and construction?
7. In your opinion, how did the time required to complete the lesson compare to the benefit of the additional material?

Nearly identical questions were asked using a paper-based survey in the Sustainable Construction class regarding the overall BPA Certificate. Nearly identical questions were also asked using an online survey delivered via Canvas to students in the Integrated Construction Leadership class. Finally, an abridged paper-based survey was administered in the Sustainable Construction class at the end of the semester regarding the two field trips attended by the students. It should be noted that Autodesk's Sustainability Workshop also has the ability to generate "reports" regarding usage and performance of training modules for individuals and the group. However, these reports, both during semester and after completion, were generally inaccessible to the researchers because the web-site would not generate a majority of the reports listed when queried. Accordingly, the research does not include any data from the BPA website.

4 RESULTS

The following data were collected from students in the Sustainable Construction. Over the course of the semester, they were asked to list three concepts from the modules that a) overlapped with course (lecture or reading) material; or b) were valuable for understanding sustainable design and construction in general. The authors performed preliminary coding to group themes and concepts, as well as ranked the number of occurrences across student responses. Only coded categories with two or more entries by individual students were included to provide triangulation. Finally, these concepts were independently evaluated by the authors as to whether or not they generally contributed to student understanding of 1) systems thinking or an understanding of interconnectedness, or 2) action-orientation change-agent skills. Results are presented in Table 1. The aggregate scores represent the total number of instances that student responses contained a concept related to either competency.

Table 1: Student-identified sustainability concepts addressed in seven BPA modules, as they relate to promoting two sustainability competencies

Module	Concept	No.	Promotes Systems Thinking	Promotes Change-agent skills
Building Performance Analysis (BPA) Introduction	Net-zero Building	9	X	X
	Environmental impacts of building	8		
	Building performance analysis (BPA) and Building Information Models (BIM)	8		X
	Life-cycle Analysis	6	X	
	Occupant Comfort	4	X	
	Modeling Level-of-detail (LOD)	2		X
	Systems Thinking	2	X	

	Daylighting and natural ventilation	2		X
	Energy Efficiency	2		
	Aggregate score		21	21
Energy Literacy and Building Loads	Building Loads (including thermal, occupant)	14	X	
	Design for climate	5	X	X
	Building Envelop	4		X
	EnergyStar	2		X
	LEED	2		X
	U-value, R-value	2		
	Passive Design	2	X	X
	Aggregate score		21	15
Climate and Weather Analysis	Thermal Comfort	10	X	
	Wind/ventilation	8		X
	Design for climate	6	X	X
	Humidity	4		
	Wet/Dry bulb temperature	4		
	Heating and Cooling degree days	2		
	Thermal Mass	2	X	
	Psychrometric chart	2		
	Passive Heating and Cooling	2	X	X
	Aggregate score		20	16
Solar Measurements and Strategies	Solar Angles	13		X
	Thermal Mass	11	X	
	Passive heating / cooling	8	X	X
	Shading / overhangs	4	X	X
	Sun Spaces	2		X
	Trombe Wall	2		X
	Aggregate score		23	29
Wind and Airflow Strategies	Airflow/ Natural Ventilation	14	X	X
	Thermal Mass	5	X	
	Cooling Towers	5		X
	Renewable Wind Energy	4		X
	Thermal Chimneys	3		X
	Building Orientation	3	X	
	Aggregate score		21	26
Daylighting Strategies and Analysis	Daylighting Design	10		X
	Daylighting	8	X	
	Color Temperature	5		
	Lighting Control	4		X
	Electric lighting	3		X
	Glare	3		
	Building massing and orientation	2	X	
	Glazing Characteristics	2		
	Aggregate score		10	17
Whole Building Energy Analysis	Thermal performance of buildings and materials	11	X	X
	Interpreting energy modeling results	6		X
	Glazing Characteristics	6		
	Systems Thinking	4	X	
	HVAC System performance	3		X
	Building Envelop	3		X
	Aggregate score		14	23
	Total		130	147

In aggregate, two or more students identified a total of 42 concepts which were included the seven BPA modules as relevant to sustainable design and construction principles. The most frequently mentioned concepts included building loads; natural ventilation/airflow and solar angles. The authors assessed which of the concepts listed related to systems thinking, change-agent skills or both. Results of this coarse, weighted assessment indicate that while the modules support both types of sustainability competencies, they promote approximately 13% more change-agent skills, which is not surprising given the tools-based nature of the online modules.

In the post-module surveys, students were also asked to use a five point Likert scale from 1 (low) to 5 (high) to quantitatively assess the value and efficiency of the independent modules. These results are summarized in Figure 1.

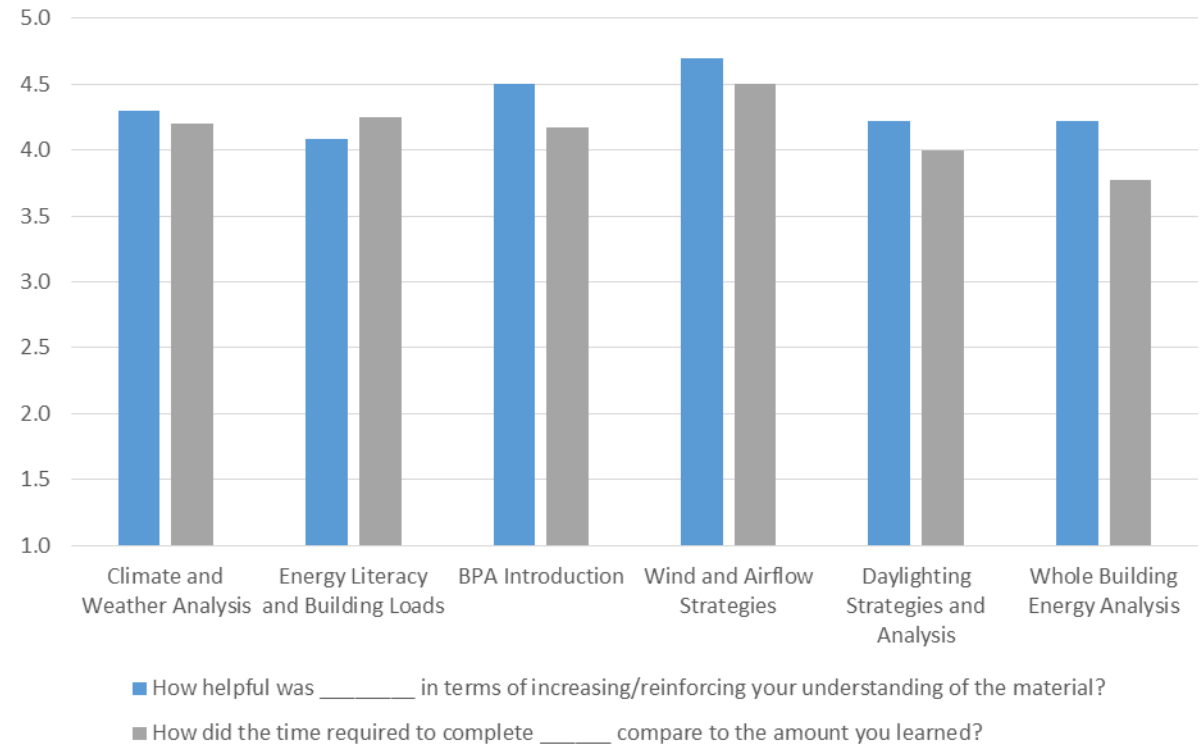

Figure 1: BPA Module Assessment

Students assessed the Wind and Airflow Strategies module as the most helpful with regard to increasing / reinforcing sustainable construction material, followed by the Solar Measurements and Strategies and Climate and Weather Analysis modules. The Wind and Airflow Strategies module was assessed as most favorable in regard to time required versus amount learned, followed by the Solar Measurements and Strategies, then Energy Literacy and Building Loads. Across all modules, assessments were uniformly favorable with all assessments scoring higher than four on a five point scale.

In order to provide a control for the online format of the modules, three end of semester surveys were also administered: two more in the Sustainable Construction class and one in an Integrated Construction Leadership class. In these surveys students were asked to use a five point Likert scale from 1 (low) to 5 (high) to assess the amount of learning, time effectiveness, and the value of learning relative to their professional career for the BPA Certificate, Procore Certificate and class field trips, as shown in Figure 2. Note, since no certification is given for field trips, students did not rate the value of such a credential.

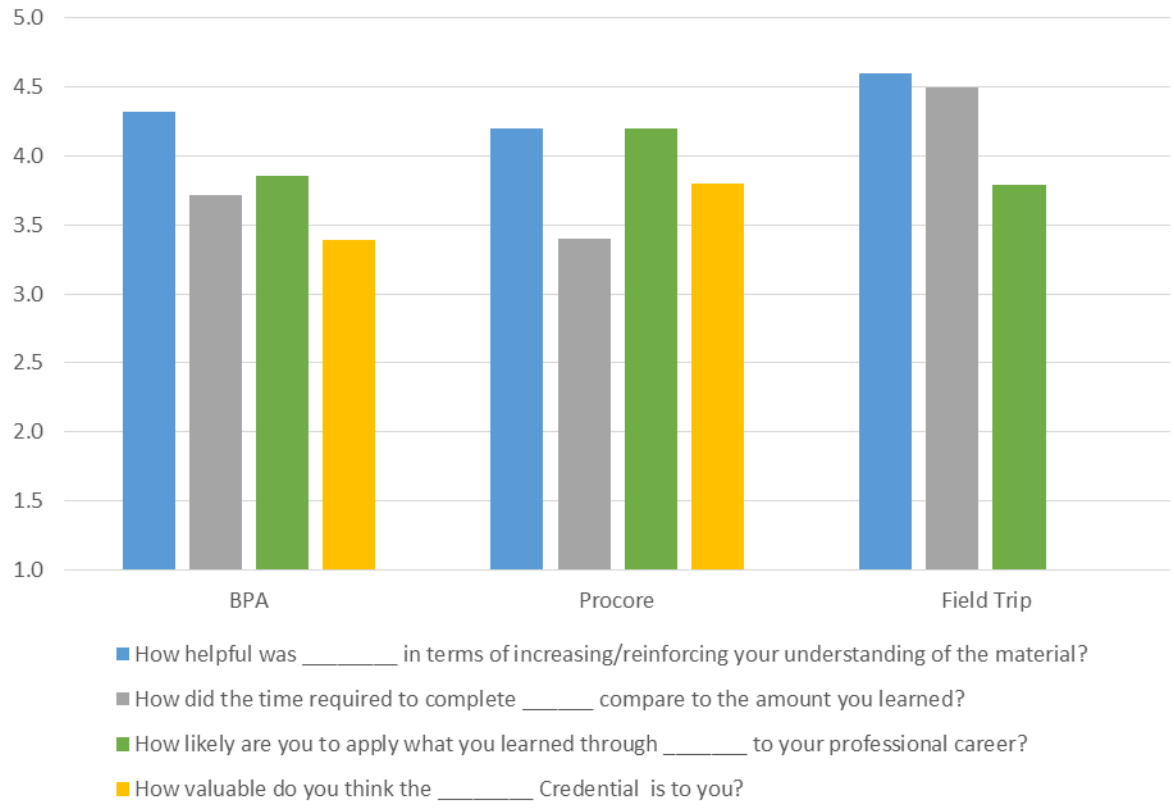

Figure 2: Delivery Methods Assessment

Overall, results were relatively uniform with average scores ranging from 3.4 to 4.6 on a scale of five. Students assessed field trips as most helpful in terms of increasing / reinforcing understanding of the material followed by BPA online program and closely by Procore online program. Students also assessed field trips as being the most time effective learning followed by BPA and Procore respectively. Students assessed the Procore Certification program as the most likely to be applied in their professional career, followed by the BPA Certification program and, lastly, field trips. Finally, student assessed the Procore Certification as a more valuable credential than the BPA Certification. By way of validation, average student assessment of how helpful each individual module was (4.33) was similar to their assessment of the overall Certificate (4.21) at the end of the semester.

An additional question was asked with regard to the BPA Certification: Do you plan to add your BPA Certification to your a) Resume or b) LinkedIn profile. 71% of students responded they intended to add the certification credential to their resume and 79% of students responded they intended to add the certification credential to their LinkedIn profile. Such data is not available regarding students' attitudes towards the Procore Certification. However, student attitudes generally appear to agree with industry professionals' that Certifications add value and are a potential differentiator within the construction industry.

Finally, on average, students reported spending a total of 24 hours to complete the BPA Certification, four hours to complete the Procore Certification and total of seven hours for the field trips. While, as previously noted, BPA system reports did not consistently work, inspection of available logged time suggested, anecdotally, that students tended to over-estimate the amount of time they spent on the modules, with the total time appearing to be closer to 20 hours rather than the 24 self-reported.

4.1 Discussion

The contribution of this preliminary research is to assess the effectiveness of Autodesk's BPA Certification in promoting systems thinking and change-agent skills as related to increasing their understanding of

sustainable development in engineering education. Students identified 42 key sustainability concepts after completing BPA's seven independent modules with 18 (43%) concepts identified by the authors as promoting systems thinking and 24 (57%) as promoting change-agent skills. As such, students identified more instances of change-agent skills than system thinking across the modules. However, in both cases, the modules appear to provide a significant contribution towards teaching basic principles related to sustainability in engineering. Both for individual modules, and overall, student assessment of the effectiveness of the online training was largely positive, roughly 4.3 on a scale of 5.0. Finally, the large majority (>70%) of students indicated that they would list the BPA Credential on a resume, LinkedIn profile or both.

In summary, the BPA online training appears to be a reasonably valuable and effective enhancement to teaching sustainability in the construction engineering class surveyed. In particular, findings suggest that online sustainability training effectively and efficiently promotes change-agent skills, followed by systems thinking. By way of comparison, students rate a similar online training, related to project management as more effective, yet slightly less efficient. However, students stated they are more likely to apply the tools and skills related to project management to their professional career than the sustainability tools and skills learned online. This preference may be more indicative of attitudes in construction engineering in general, rather than a result of the trainings themselves. Nevertheless, it is worth noting that there does appear to be a perception among students that they will not use skills related to sustainability in industry. Finally, all results are not generalizable due to small sample size of both classes surveyed.

5 CONCLUSIONS AND FUTURE WORK

Engineering education faces a challenge to effectively integrate sustainability concepts and promote sustainability competencies. Furthermore, as online delivery methods become more wide-spread, more research is needed to assess the effectiveness of online teaching in general, and online teaching as it relates to sustainability in particular. While it is difficult to assess the value of educational tool and strategies, this research begins to provide feedback and assessment of Autodesk's BPA online modules, otherwise known as Autodesk's sustainability workshop. Findings suggest that such online learning is generally effective, although real-world field trips remained a more popular teaching enhancement according to students studying sustainable construction. Future research is recommended to further explore differences between virtual versus real-world learning methods to promote sustainability competencies for engineering students. Such research is critical, given the applied nature of engineering with a high reliance on technological tools and skills, as well as the significantly differing amounts of work and preparation required by educators to facilitate such experiences. Future research should also explore what topics or competencies may be best suited to online delivery and how and where such delivery methods could be used to expand as well as reinforce traditional in-class teaching delivery methods related to sustainability.

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