BIM-based Interdisciplinary Collaborations in a Student Project Competition

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Abstract. Architecture is a profession that requires collaboration among professionals from various fields. Despite the important nature of these interdisciplinary collaborations, architecture students rarely obtain the opportunity to learn about the work areas of other stakeholders and the practice of working together. In all sectors there is a growing need for professionals who possess in-depth knowledge in their own disciplines and also develop an understanding about other related disciplines. In a setting of a student project competition, this article examines how students from various AEC fields collaborate using BIM as a common data environment and emphasizes several considerations for implementing interdisciplinary collaborations in curriculums of architecture schools in students' perspective.

Keywords: Interdisciplinary Collaborations, Architectural Design Studio, BIM, Building Information Modeling

1 Introduction

Due to the introduction of sophisticated free building forms, new materials and construction methods, the number of stakeholders involved in building design and construction has steadily grown. Architects serve as a member of a large team consisting of many stakeholders (Kirk and Spreckelmeyer, 1988). The exchange of information between these stakeholders is critical and carried out electronically in most cases.

Until very recently building professionals often worked together by exchanging CAD files during building design and construction. CAD-based collaborations frequently bring about translation errors between different applications, coordination problems in project documentations and production of redundant information, hence time and labor losses that cause financial burdens for building firms (Gallaher and O'Connor, 2004).

BIM (Building Information Modeling) is a relatively new collaboration platform that is highly promoted for building professionals as a common data environment

(EUPPD, 2014) and supported by collaboration protocols that enable professionals to work together (BS 1192, 2007; Penn State, 2011).

Interoperability is one of the strengths of BIM-based collaborations. In a team-based approach architects, engineers and other allied stakeholders develop and work with a common data model from early to final stages of a building project (Fig. 1). The ability of utilizing an interoperable model by different stakeholders (a) enhances the production of consistent project representations, (b) facilitates the project revisions, (c) reduces replications in projects and (d) improves the coordination between project documents (Ofluoğlu, 2014).

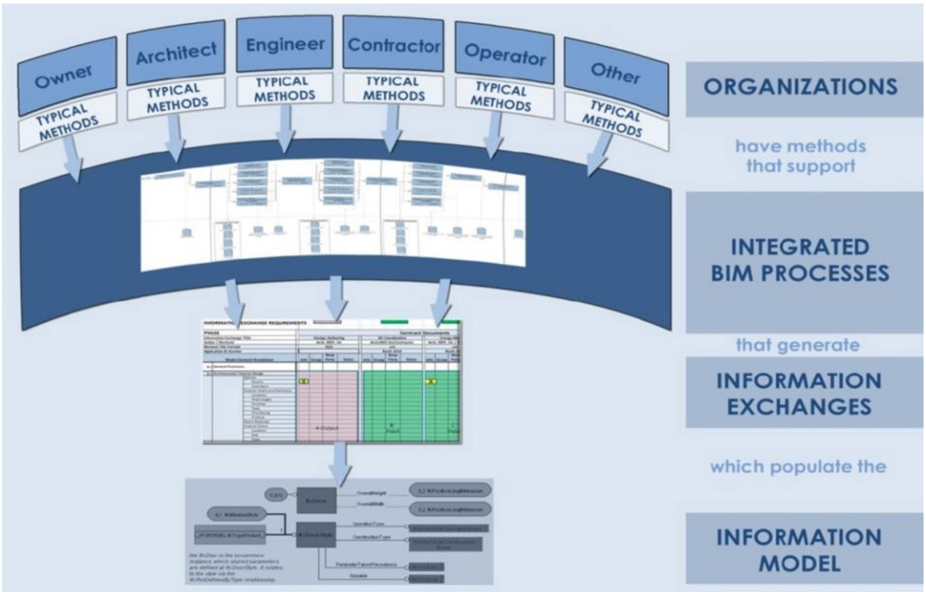

Fig. 1. Process of building information model with stakeholders (Penn State, 2011)

Interoperability is also significant for Integrated Project Delivery (IPD), a prevailing project delivery method that encourages project stakeholders to work together, to exchange information and to share risks and rewards, as part of the same team from the early stages of the project. Utilization of a plan or systematics in designating the roles/responsibilities of project stakeholders, specifying project phase(s) in which participants will involve and the content and format of the information they will excange is critical for the success of IPD.

BIM serves as an enabling technology for Integrated Project Delivery. Collaboration and data management is an aspect of BIM project processes (Fig. 2). Collaboration protocols that allow different stakeholders to work together are supported in BIM (BS 1192, 2007, Penn State, 2011). Stakeholders can work in parallel on the same project with defined a team hierarchy, a discipline-based project organization, user authorizations, common data formats and server-based collaboration opportunities.

Third-party software environments are also built on this collaboration through the interface of BIM software.

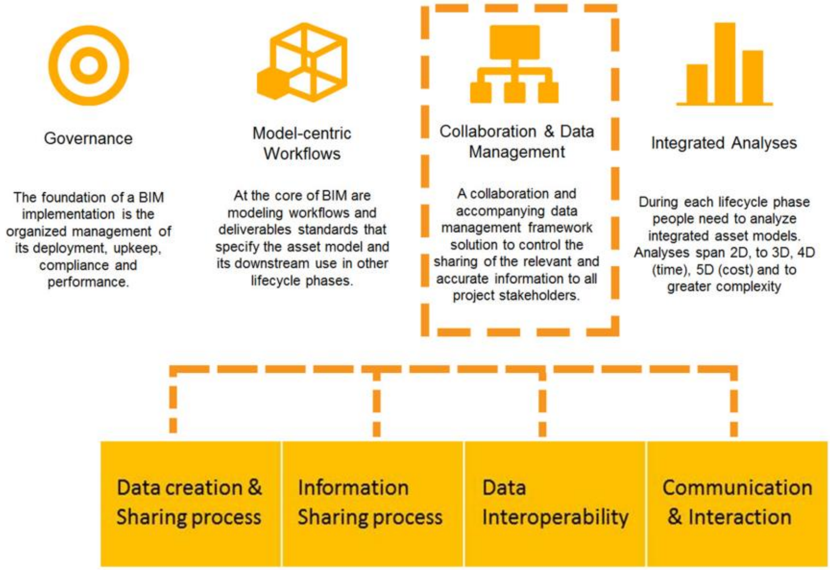

Fig. 2. Collaboration and Data Management in BIM Project Processes (Koppula, 2012)

2 Use of BIM in Interdisciplinary Collaborative Learning Environments

In education, BIM also constitutes a platform that helps developing important operative skills and understanding through simulations and virtually built projects. Due to its semantic data structure, a BIM building model can be subjected to various simulations, since it possesses all the qualities of a physical building. For instance, in order to predict performance and sustainability of their designs, students can examine their models' climatic behavior and energy use with environmental simulations. With the availability of 4D/5D BIM simulations, that integrate time and/or cost parameters, it is possible to determine the potential problems with construction sequences, timing and cost before the actual construction. It is also possible to detect possible conflicts between BIM models of different disciplines and view them both graphically and in reports in order to correct them. There are various research studies that examine the integration of BIM into design education (Guidera, 2006; Ambrose and Fry, 2012; Kocaturk and Kiviniemi 2013).

The Integrated Project Delivery settings described above also have implementations in educational environments (Ilal et al., 2009; Boeykens, et al., 2013; Tomasowa, 2015). Students experience the collaborative nature of IPD beginning from early phases of design and learn the priorities, interests and views of students from allied disciplines as if they work in a professional project environment.

One of the earliest examples of these collaborative environments is the interdisciplinary BIM studio held at the Pennsylvania State University in the USA. This BIM-based studio environment has been carried out since 2009 with the participation of students from architecture, landscape architecture, civil engineering, mechanical engineering and project management departments. It is an elective course that is planned to be transformed into an alternative design studio. Students collaborate in a BIM environment and have an experience working with students from other disciplines (Fig. 3). The feedback received from students reveals that due to collaborative group activities they learn more about the process for coordinating with members from other disciplines and understand their concerns (Holland et al., 2010).
Similar multidisciplinary design studios are also organized at University of Illinois, University of Florida, University of Maryland, Kent State University in the USA, Salford University in the UK University of Leuven in Belgium, and Sydney University in Australia.

Fig. 3. Interdisciplinary BIM Studio at Penn State University (Holland et al., 2010)

3 The “Design Together” Competition and Survey Research

The “Design Together” competition is one of first efforts creating a similar interdisciplinary work environment to the studios mentioned above in Turkey. It is aimed at promoting collaboration among AEC students and creating an awareness of BIM in universities. The competition was organized by the Istanbul Technical

University Engineering Preparatory club and sponsored by several Turkish software and construction companies in 2016.

In this interdisciplinary working environment students of three disciplines (Architecture, Civil Engineering and Mechanical Engineering) were allowed to participate as teams. 24 teams consisting of 112 students from 12 Turkish universities enrolled in the competition. Members of participating teams were given a short training on BIM software and the culture of collaboration in School of Civil Engineering at the Istanbul Technical University (ITU) (Fig. 4).

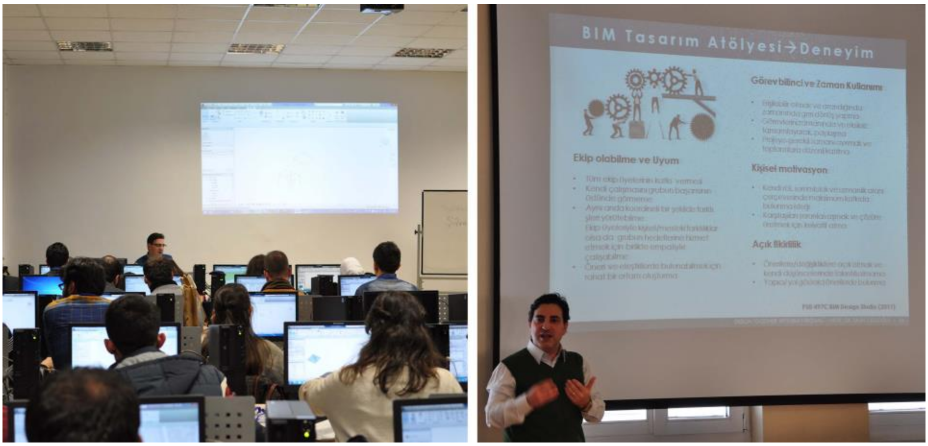

Fig. 4. "BIM Sustainability Analyses" and "Culture of Collaboration" trainings

The project involves designing a 2000 m^2 student activity center at the ITU main campus. The building contains different social-cultural spaces that enrich the campus life of students and needs to incorporate high-performance and sustainable design strategies utilizing energy efficiency and renewable energies. In this context, BIM is considered to be the key working method in achieving a high performance building in a collaborative setting.

The teams were asked to prepare architectural, structural and mechanical BIM project models, to conduct sustainability analyses and to produce clash detection reports between models along with a 4D model that illustrates the sequence of construction processes and cost. Most modeling operations and analyses were executed with software products of Autodesk, the main sponsor of the competition. Six teams submitted their final projects and three of which received awards for their achievement (Fig. 5).

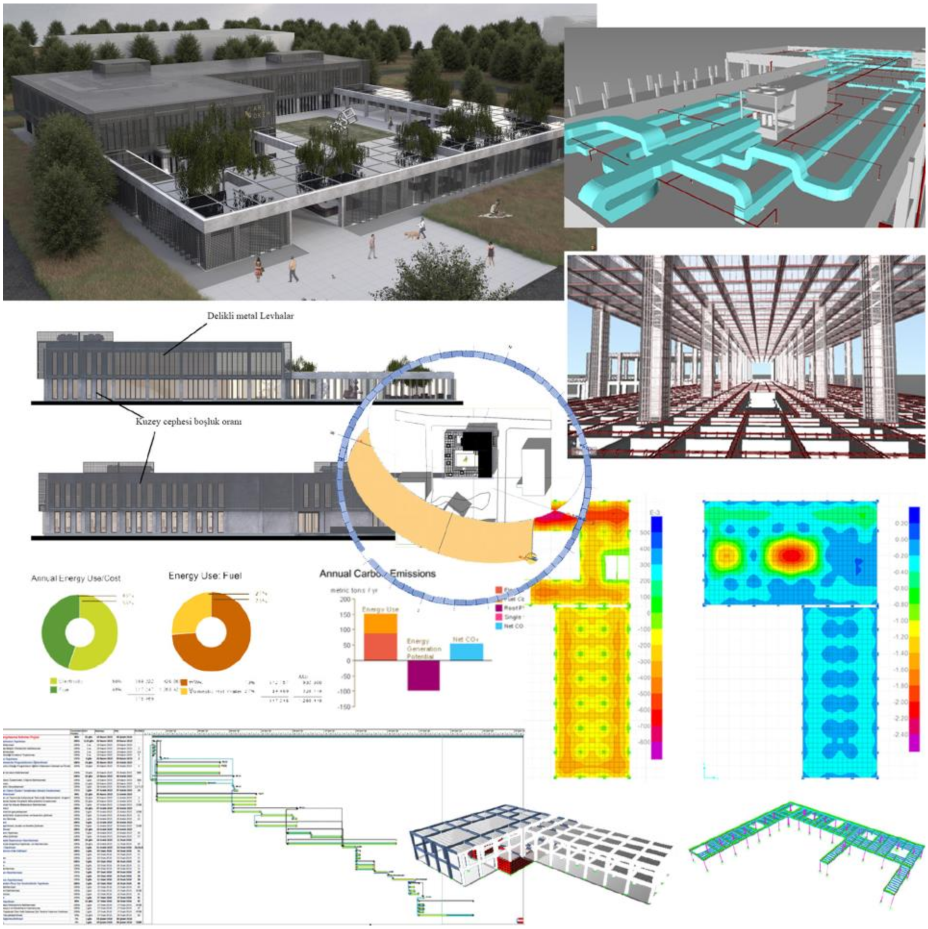

Fig. 5. The project of "KTU-Together", the winning team

Two surveys were conducted with members of participating teams. Both surveys included questions related to interdisciplinary collaboration processes, the role of BIM as a common data environment and the implementation ideas for interdisciplinary collaborations in educational curriculums in architecture and engineering schools.

The first survey was completed before the initiation of the project when teams came to Istanbul for the training. 56 participants that comprised of 20 architecture, 20 civil engineering and 16 mechanical engineering students participated in this survey. The objective of the first survey was geared towards understanding the students' expectations of working together with others and learning if they considered any systematics or implementation plans for project tasks.

The second survey was conducted only with members of six teams who submitted their final project. It contained 16 participants consisting of 4 architecture 11 civil engineering and 1 mechanical engineering students. This survey was conducted at the end of the competition and particularly aimed at understanding the extent to which the initial expectations of collaborative working are met and assessing the potential uses of interdisciplinary collaborations with BIM in educational curriculums.

All the survey data were processed and interpreted. One of noteworthy findings of the survey was that most teams had some type of a work plan to organize collaborative processes and information exchanges similar to BIM implementation plans utilized in AEC firms. According to the survey results BIM also appeared as an enabling collaborative environment that helped the progression of interdisciplinary work, and collaborative interdisciplinary environments are found to be beneficial for architecture and engineering school curriculums.

The following are the results of the questionnaire survey in three main categories. In each category both quantitative analyses and direct quotes of survey participants were presented.

3.1 Experience of Working Together with Other Disciplines

Collaboration among AEC stakeholders is a common practice. However, students generally do not have the opportunity to work with others from different disciplines during their education, with the exception of short internships, student club activities and competitions.

The "Design Together" competition offered students an experience similar to the Integrated Project Delivery environment in the real world. A very large proportion of the students found this experience positive (90%). Students also stated that working together is primarily useful for (a) sharing expertise decisions and responsibilities in a holistic project (91%), (b) understanding the roles and needs of stakeholders from different disciplines (95%), and (c) anticipating potential problems during construction (86%). Two students said that:

"After architectural design is completed and its constructability becomes the issue. At various phases it is necessary to work with other disciplines and decide together. This competition is much like a pre-vocational training that enables us to fulfill our capabilities in the real business environment…"
"Architectural projects can be refined with the civil engineering and electrical-mechanical departments, producing more realistic results."

Although working together with other disciplines is found beneficial as stated above, it was also found to be challenging. 60% of members of the six teams who submitted their final project claimed that the interdependence of team members in the process led to occasional blockage in the information flow. This, in turn, caused delays in project delivery process. Another difficulty stated by students was that allocating common physical meeting times was difficult due to busy working schedules. This was confirmed by more than half of the team members filling in the second survey. In order to overcome this difficulty, applications such as WhatsApp and Skype were used.

Engineering students particularly emphasized the importance of utilizing a work plan to ensure smooth information flow and to coordinate processes. In the real world, too, it is critical, especially for integrated project delivery applications, to use an implementation plan to specify collaborators' roles, project processes and phases of information exchange. In this competition, 70% of the members of the teams who submitted the projects stated that they worked according to a plan. One participant stated that:

"Certain phases of the project can be completed effectively in a specified period by setting out a plan, which determines the deadline for submission of the competition project."

Having a common team vision (83%) and respecting others' ideas (64%) were considered very important for working together by survey participants. One participant described this attitude as follows:

"As a team we worked in collaboration by exchanging information and respecting each other's ideas and insights. Together we did brain storming and corrected our mistakes. Thus, we have combined different views. At the same time, this cooperation has enhanced our workforce."

Despite such value attributed to teamwork, in the second survey conducted after the project submission, more than half (56%) of the students said that they did not work with the same vision and understanding. The fact that only 6 of the 24 teams in the competition delivered their project might support this finding and suggest that there may be a lack of co-operative culture in various teams. Difficulties in working together might arise from different interdisciplinary priorities and views. One student claimed that:

"... my teammates who are engineers have more rational approaches. I am convinced that they will make fun of my aesthetic worries by saying "a typical architect's attitude" A tough process is waiting for me. They consider architecture as making a house from cardboard."

3.2 Utilization of BIM Tools in Interdisciplinary Collaborative Projects

One of the most important challenges for the teams was that they were required to develop their project in BIM environments, which they had never used before. More than 75% of the students who participated in the competition did not use any BIM software previously. Nine of the architectural students and four of the civil engineering students used BIM software; none of the mechanical engineering students had any BIM experience. In real professional practice in Turkey, engineers' BIM software usage rates are lower than that of architects as well.

Of the survey respondents %77 stated that there was not any BIM related courses in their schools. They also mentioned that their school faculty do not have much information about BIM software and do not encourage its use. Some used the following phrases for the situations they encountered:

"They want a hand-made model (instead of a BIM model), they are prejudiced."

"They generally think that we should not use it and say that they (BIM software) are the worst among all three dimensional software."

"So far no one said anything positive about BIM; they even tried to convince me to use other applications."

Three questions were asked to students about their attitudes towards BIM. In the first question, they were asked to choose their five most important reasons for using BIM software. Students appeared to choose the tasks with which they might be familiar from geometric modeling software instead of marking BIM-specific features only.

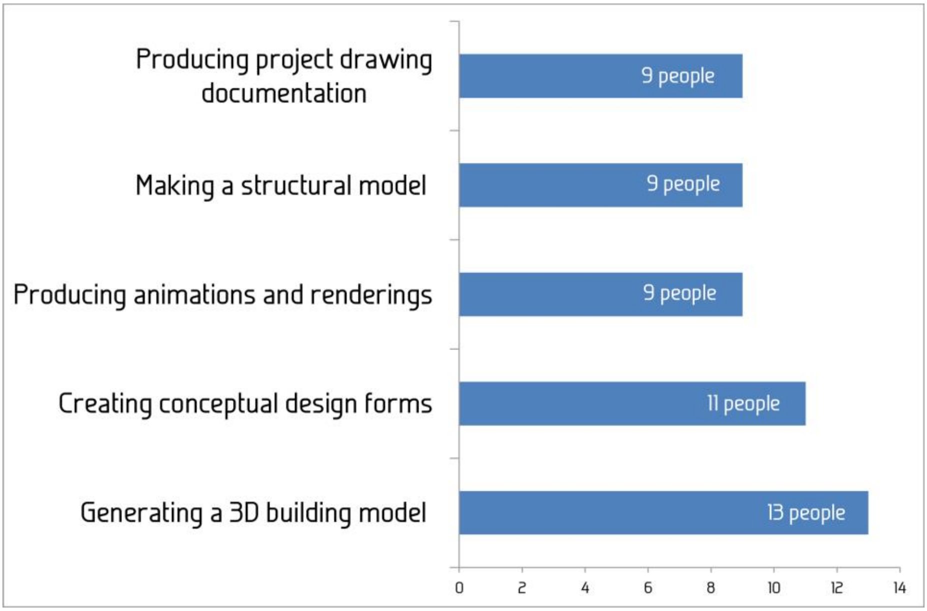

Fig. 6. Five important reasons for using BIM for survey participants

In the second question, students were expected to mark three of the most important capabilities of BIM software. The resulting ranking reveals that more general features of the technology is preferred over task specific operations such as sustainability analyses, clash detections and 4D simulations.

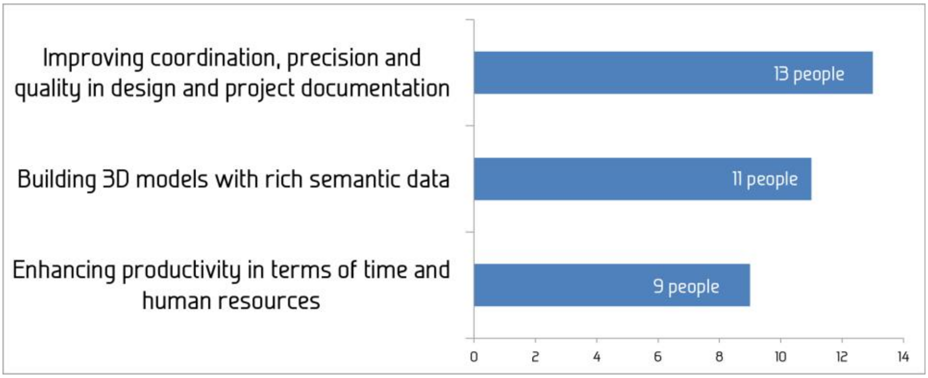

Fig. 7. The most important capabilities of BIM according to survey participants

The third question was about which areas BIM software can contribute to team working and collaborative projects. The three areas that are most preferred by participants are:

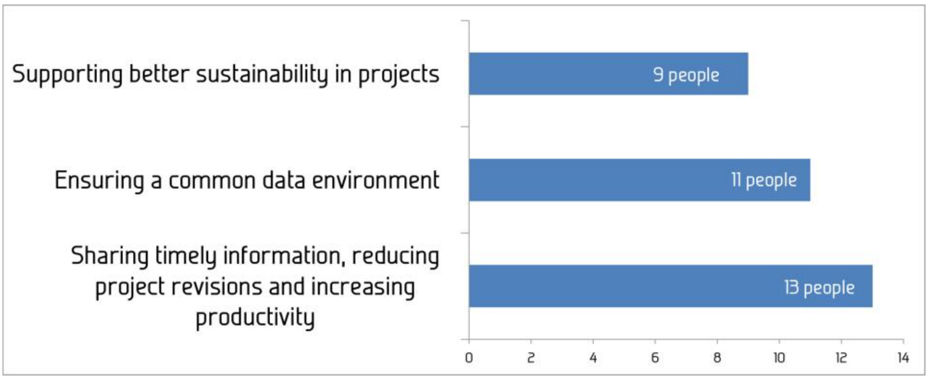

Fig. 8. The most preferred features of BIM according to survey participants

3.3 Interdisciplinary Collaboration Opportunities in Academic Programs

Another area examined in the survey study was the possibility of integrating interdisciplinary collaboration environments into undergraduate and postgraduate programs in AEC disciplines. In the second questionnaire, students were asked whether such collaborative settings could exist in an educational program and how it could be achieved.

All the students (16 people) from the teams that delivered their project stated that it would be beneficial to have a project course based on interdisciplinary collaborations like this one in the curriculum. They think that such a course should be offered in the later years of the curriculum, specifically in the third year (6 people) or the 4th year (10 people). Some students also believe that this course must be compulsory (10 people). Students emphasized that the important asset of this course would be to create an environment that is similar to the working culture in the real world (16 people) and to allow people from different disciplines to get to know each other (10 people). Two participants said that:

"*Through this course, students will have the opportunity to see the real life problems....*"

"*It is absolutely crucial to have such a course that brings all the disciplines together... In this type of a course, students may encounter real business world problems. This course can provide students with solutions to these problems.* "

Some students suggested that this collaborative project course can be organized as a construction project studio, a diploma project studio or a workshop outside the curriculum. They also implied that there must be good coordination between departments and faculty members, and the buildings/campuses of participating disciplines should be in close proximity to each other. Several students recommended the following educational scenarios:

"*Existing project studios can be revised (to accommodate other disciplines).*"

"*... departments can offer joint projects, especially in diploma projects of the final year.*"

A significant number of the students (63%) feel that the use of BIM software as a common data environment should be compulsory and knowledge of BIM should the prerequisite for interdisciplinary courses that require collaboration.

In the first survey that involved more participants, some students also expressed reservations regarding the integration of interdisciplinary collaborative environments into their educational curriculums. They pointed out that it would be difficult to implement this new teaching methodology in already rigid and intensive course curriculum. They also had doubts about the existence of visionary teaching staff who would implement this new method. They mentioned that:

"*The teaching staffs have their own instruction methods and behaviors. I do not think they will be open to different ideas*"

"*Our school program is already busy, so it is difficult to implement it. BIM requires intense work and it is hard to do that in addition to our existing studies.*"

"*Schools' administrates should be visionary (to implement it).*"

"*The students in different departments are stuck with time because of different campuses, different curricula, different exam calendars ... it is very unlikely that common courses and curriculum will be organized*"

One student also stated that instead of creating such interdisciplinary work environments in an existing curriculum, long-term internship opportunities could be considered:

"I think that every discipline must first gain competence in itself. I think that the encounter of these different disciplines should be in a pre-professional business environment, not in school. This pre-professional environment should prepare students for the real world. I think that our existing internships should be extended for a longer period of time."

4 Collaboration Opportunities in Educational Programs in Architecture

The survey results highlight the significance of interdisciplinary collaborative working environments and possible implementation options for AEC schools. Architectural programs in many schools appear not to adequately address the practice of working together with people from other allied disciplines in their curricula (Macdonald and Mills, 2011). However, in architecture and other sectors there is an increasing need for professionals who are already experts in their own field and also have a working knowledge about the fields with whose members they collaborate (Hansen and Oetinger, 2001; Buxton, Bill 2009). Some classify these people as T-shaped professionals (Kelley, 2005). There are many institutions and universities that support the type of education these professionals need and encourage interdisciplinary approaches (Bardecki, 2015; Oskam, 2009; Karjalainen and Salimaki, 2009; Holley, 2009).

There may be several ways to offer such interdisciplinary environments in architectural curriculums. Specialized design studios, elective courses or workshops outside the curriculum can be appropriate venues to offer needed collaborative skills for architectural students and to allow them to interact with students and faculties of other departments. The survey results incorporate several considerations that might influence the implementation of interdisciplinary collaborative environments in universities.

1. **Supportive BIM and digital media courses:** The prior knowledge of BIM, as indicated by survey participants, would be an asset in collaborative design studios. Availability of BIM and other digital media courses offered in earlier semesters can allow students to allocate more time for design and project documentation in design studios. Introduction of online software training materials can also offer active learning opportunities for students outside the classroom.
2. **Availability of technology-savvy staff:** One of the complaints of the students taking part in the Design Together competition was the lack of knowledgeable instructors in the utilization of BIM. In recent years, instructors of architectural design studios are expected to possess professional knowledge in architecture and to be competent in digital media. These instructors convey their knowledge of design and presentation skills using digital tools. In a collaborative context, every

discipline should be represented with one or more instructors, and one of which can be assigned as a coordinator to organize the events. In addition a teaching assistant who can help students with their day to day BIM and CAD related tasks would be an asset.

3. **Implementation plans for managing sources and actors:** It can sometimes be challenging to bring together people with different professional qualifications, priorities and working styles on a project. This can become even more difficult in educational settings where the roles and responsibilities and work schedules are not clear. The importance of implementation plans was also emphasized by students taking part in the Design Together survey. It is therefore important that project stakeholders prepare an implementation plan that will guide them to work together, facilitating, project workflow, data exchange and assignments of roles.
4. **Coordination among departments:** The course schedule of the faculty and students of the collaborating departments, the availability of classrooms and departments' physical proximity to each other can make the arrangement of physical meeting time difficult. Necessary efforts should be made to create common times and flexible schedules for all collaborating parties. This issue was also highlighted by several survey participants in this study. Utilizing electronic communication media would also be an option to meet outside working hours in case of necessity.

Overall, this study reveals that students find BIM-supported collaboration experience beneficial and would also like to see its implementations in educational settings. This research only reflects students' perspectives. This view should be complemented with further research that would examine the opinions of other participants such as teaching and research staff that take part in such collaborative environments and integrate pedagogical outcomes of this approach.

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