Collaboration support for 3D and 4D models: A pedagogical experiment applied to wooden construction

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Abstract

Through this research, we review a two-year pedagogical experiment to highlight the necessary specifications and to continue to progress towards a proposition of a new collaboration and decision-making support, well adapted to the needs of Architecture Engineering Construction. This paper presents observations from a pedagogical experiment on synchronous collective decision-making by users via digital project documents on a touch table. The experiment offers a unique context for our research on multidisciplinary collaboration observations and for 3D or 4D model use studies. Our experiment aims, first, to survey the user-perceived utility of such digital support with natural user interactions and collate suggestions for improvements to the support. For the research, both individual and group perceptions are important. Second, we describe a decision-making session actors' activity and interactions. The results will contribute to the design a collaborative decision-making support.

Keywords: Synchronous collaboration, Pedagogical experiment, 3D models, 4D models, NUI

1. Digital collaboration

Team meetings and collective decision-making (DM) have always been a part of construction project development, where multidisciplinary cooperation requires a significant effort from project stakeholders (Staub-French & Khanzode, 2007). For more than a decade, project development has used digital tools and Building Information Modeling (BIM) as common instruments (Kensek, 2014). Project teams use BIM as an information source for DM, thus they need an efficient digital collaboration environment (Achten, 2002), with quality interactions (Tory, Staub-French, Po, & Wu, 2008).

Professionals and academia continue their research for better ways to collaborate and to manage projects more efficiently (Oxman, 2008). Following this global dynamic, pedagogical experimentation needs to progress in step with the industry (Pikas, Sacks, & Hazzan, 2013). Academia is well positioned to develop new methods of innovation, knowledge growth and transmission of practices, in addition, academic framework provides a good context for experiments.

This paper summarizes a pedagogical experiment on synchronous collective decision-making with a digital support for project documents visualization and interactions: a multi-touch table with the synchronous co-located collaboration software "Shariiing"1 by "Immersion"2. The Section 2 of the paper overviews the pedagogical context of experiment, provides specifications for the Digital

1 https://www.shariiing.com/
2 https://www.immersion.fr/

Collaboration Table and describes Collaboration Sessions. It concludes with a description of the experiment feedback collection methods. Next, the Section 3 presents main findings on DCT usability scores by different user categories, and their suggestions for the collaboration support improvements. Finally, the feedback results are emphasized in discussion section, and followed by experiment conclusion and future perspectives.

Also, this study is a part of an international research project 4D Collab3, which aims to the design a new collaborative 4D-based (3D+time) decision-making support. The project team is composed of research and industry partners (including "Immersion"). The pedagogical experiment results will contribute, together with professionals' collaboration experiments (not covered by this paper), to design with 4D Collab the new collaboration tool.

2. Overview of the experiment context and methods

2.1 Main experiment steps

The *digital collaboration pedagogical experiment* (the experiment) introduced a digital support for weekly meetings on project progress. Such support has to offer a homogenous interface for all project documents to avoid software switching. Also, it must offer democratic interactions, such as used in natural user interfaces (Steinberg, 2012), along with ease of learning for participants as well.

The experiment had two Phases, the Phase 1 in 2018 and the Phase 2 in 2019 (Fig.1). The Phase 1 was conducted for the Wood Challenge[4] (Section 2.2) exercise in 2018, the Step 1: Wood Challenge, design and construction project phases; Step 2: collection of the users feedback and the adjustments to the collaboration sessions (Section 2.3). The feedback showed the utility of digital collaboration technology and suggested ways for next year improvements. In Phase 2, as Step 0, with the aim of training all the students to be efficient with a digital collaboration table during the upcoming Wood Challenge 2019, the table was introduced to them in the 1st semester for a Design Project. Steps 1, 2 have followed to conclude the 2nd phase of the experiment.

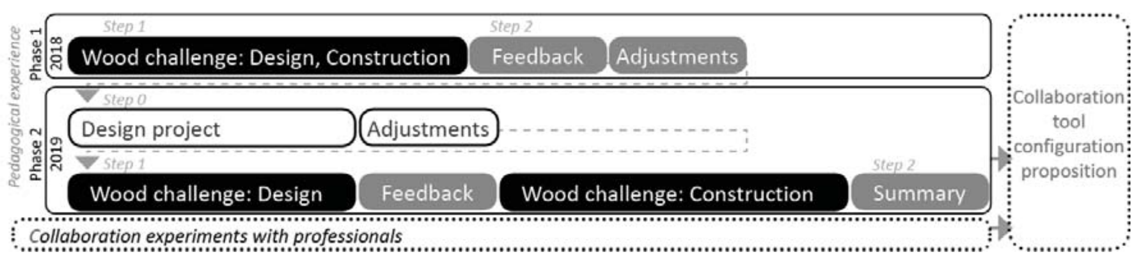

Figure 1: Schema of the digital collaboration experiment steps

2.2 Pedagogical exercise: 'Wood Challenge'

Every year, at ENSTIB 5 Engineering School of Wood Technologies and Industry, the "Architecture, Wood, Construction" 6 postgraduate program launches a pedagogical design and construction exercise called "Wood Challenge"7. The challenge's main tasks are to design and then build, in teams, a small project with a wooden structure (Fig. 2). Hence, it encourages students to foresee possible problems with their design choices, and to anticipate the answers to construction problems.

The students work in multidisciplinary teams, comprising of an architect, a wood structural engineer and a civil engineer. Also, every team has two additional members: a wood construction professional and an exchange student in architecture or engineering. The diversity of the team

3 https://www.4dcollab-project.eu/
4 Original French Défis du Bois (http://www.defisbois.fr/)
5 École Nationale Supérieure des Technologies et Industries du Bois (http://www.enstib.univ-lorraine.fr/fr/)
6 Original French «Architecture Bois Construction"(http://www.nancy.archi.fr/fr/master-genie-civil-1.html)
7 Original French « Défis du Bois » (http://www.defisbois.fr/)

emphasizes the importance of efficient communication and collaboration to the students. All teams work on a defined project type, which varies every year with the same deadline and technical requirements (quantity of materials, structural elements, tools, etc.). Once the design and pre-construction preparations have been completed (6-7 weeks in the beginning of the winter semester), the teams then proceed to construction (1 week in May). The projects are fabricated and assembled on campus. They must not exceed a surface of 15m2 and a height of 3.8m, and have no more than 10 disassembled modules or elements in order to fit into a truck for transportation to the project installation site. The restricted construction time and added competition element fosters students' abilities to foresee many construction organizational aspects and see optimization for the project design and construction.

Figure 2: Examples of Wood Challenge projects

2.3 Description of the Digital Collaboration Table

Teachers and students weekly gathered around a digital collaboration table (DCT) for project review meetings. The DCT's main element is a multi-touch screen (46" HD, infra-red touch recognition frame), which is embedded in a wooden table frame (Fig. 3). The screen is connected to a PC running "Shariiing" software, a multiuser collaboration environment by "Immersion". The software versions: "Shariiing Research" in 2018 (Fig. 3), "Shariiing Advanced" 8 in 2019 (Fig. 4).

Users interacted with the table with touch gestures (fingers), simple touch-pen, some used a wireless mouse to manipulate distant laptop. The use of Shariiing allows: 1. to visualize construction project documents (plans, sections, 3D models, schedules, etc.), 2. to share the same view even being on different sides of the table 3. to manipulate the documents with touch gestures ("move", "pinch", "zoom", "drag", "click"), 4. to annotate temporarily, permanently (Fig. 3), 5. to sketch.

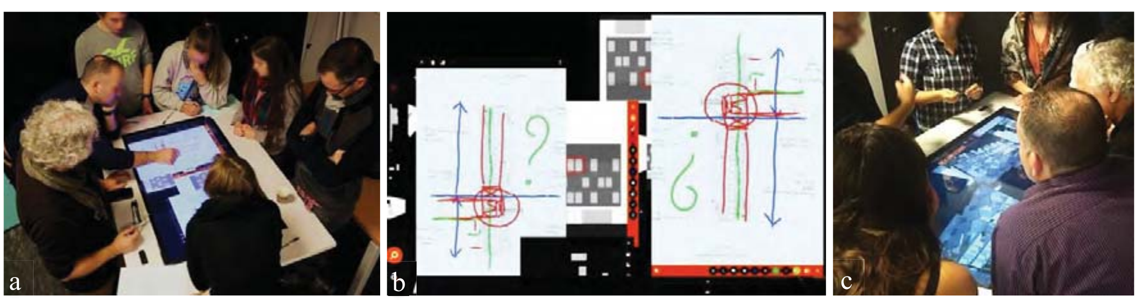

Figure 3: DCS with Shariiing Research: a,b façade detail annotation, c. 3D visualization and discussion

8 Shariiing specifications and functionalities (https://www.shariiing.com/data/documentation/Shariiing%20specifications.pdf)

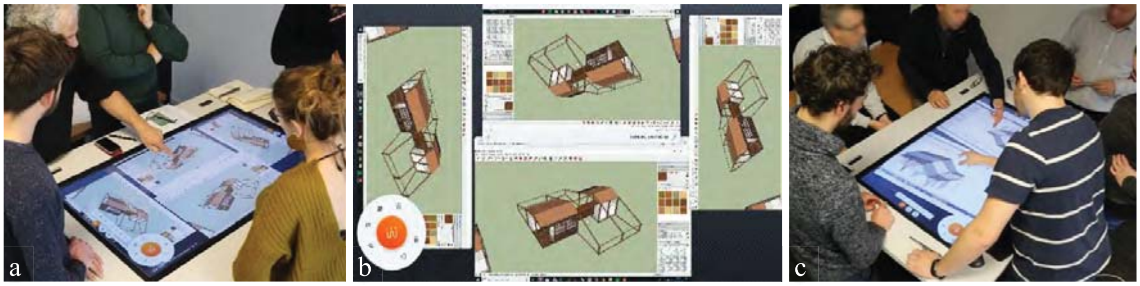

Figure 4: Digital Collaboration Session with Shariiing Advanced, interactions with 3D models

The main principle of the software use is the same for these versions, the Advanced version's interface is more minimalist and offers more fluid interactions, also 3D models visualization is offered with the screen sharing. For now users may only save an annotation on a project document as a new 2D image (screenshot). With Shariiing Research, the 3D model (.ifc, .obj) visualization and fluid interactions are possible, but it does not allow access to the model hierarchy. However, DCT offers visualization and touch interactions with a distant user. Thus, when using Shariiing Advanced, it is possible to share a view from users' laptop with a BIM viewer or design software (e.g. Cadwork (Fig.6a), Navisworks (Fig.6d), SketchUp (Fig.4a,b), etc.) directly to the collaboration environment, and to keep natural interactions and simple annotations (Fig.4a,b).

Further research aims to better adapt mentioned functionalities to AEC needs. In addition, we must acknowledge the equipment limitations, such as the screen size and resolution, or team's collaboration methodology.

2.4 Digital Collaboration Sessions (DCS) description

The session's main purpose was project review, starting with a brief presentation by the students of their progress to the professors. An architect, a structure engineer and a construction specialist were representing the pedagogical participants of DCS. The choice of the present professionals depended on the session purpose and on the project progress stage. They provided professional expertise and also represented a project client. For the Wood Challenge 2019, the mean session durations were augmenting with the project progress: 19 minutes in the beginning, 28 minutes in the end. In general, minimum session duration was 13 minutes through all project progress, and maximum session time was also augmenting from 29 minutes for the first session to 53 min to the last one. For Wood Challenge 2018, mean DCS duration was 23 minutes with a maximum of 37 minutes and a minimum of 18 min.

For Wood Challenge 2018 the design and construction subject were a pavilion9 for a botanical garden in Nancy, France. From the 10 student teams, only 2 interested in technology teams, as a part of experiment, were using the DCT for their weekly meetings (Digital Collaboration Sessions) with the pedagogical team members during the Design phase. Both teams were using plans, sections, rendered images, quantifications and 3D models for design development and value engineering at the meetings (Fig. 5a). Only one team managed to prepare a 4D model (Navisworks screenshot Fig. 5c, build structure Fig.2a). Yet, during the construction, the students preferred to rely mostly on printed project documentation, thus the 4D model was consulted only once a day by one member of the team (construction management role) for a better understanding of the assembled details and for monitoring.

9 Pavilions "Lignea camera"http://www.defisbois.fr/editions/edition-2018-lignea-camera/

Figure 5. a. Collective decision-making at Design phase in 2018 b.3D model review at Construction phase
c.4D simulation for one module assembling length estimation and progress monitoring

Together with the feedback (Sections 3.1, 3.2) on DCT improvements for AEC needs, students and professors suggested for the next year to introduce the DCT before the challenge. Thus, the table was used during autumn semester to work on a design project (reconstruction of an industrial site for student housing, residential buildings and a kindergarten) (Fig. 3). The teams had time to get experience with digital support for their weekly meetings, and to become independent users for their Wood Challenge. However, not all of the sessions' participants had an equal amount of time to interact with the DCT due to a larger number of participants. Also, 4D simulations were introduced to the students, and some of them decided to integrate them into the final project folder (digital) along with the project plans, sections, 3D model, calculations and quantifications. Table 1 synopsizes elements of DCS organization.

Finally, after training with the Design project, all the teams of Wood Challenge 2019 were using DCT for their weekly meetings with the pedagogical team during the Design phase of the challenge project (Fig.6). A new version of collaboration software (Shariiing Advanced) was installed on the DCT, to answer students requests for more familiar to them 3D models view (from their personal 3D modeling software interfaces) (Fig. 6a, 6b), and requests for more fluid interactions. All the teams were using a 3D model as a main discussion support. During the 2 final sessions, 5 student teams used 4D simulations (Fig.6d) to illustrate a construction sequence and logics for the elements of the project.

Table 1: Digital Collaboration summary for Wood Challenge 2108 and 2109, for Design Project

	Wood Challenge 2018	Design Project	Wood Challenge 2019
Project design weeks / construction weeks	6/1	12/-	6/1
Digital collaboration sessions (DCS) number	3	4	4
All Student teams / Teams participating in DCS	10/2	5/5	10/10
Number of Teams using 3D / 4D (at DCS)	2/-	5/2	10/5
Participants per one DCS Students + Professors	3 + 2 or 3	5 + 2 or 3	3 + 2 or 3

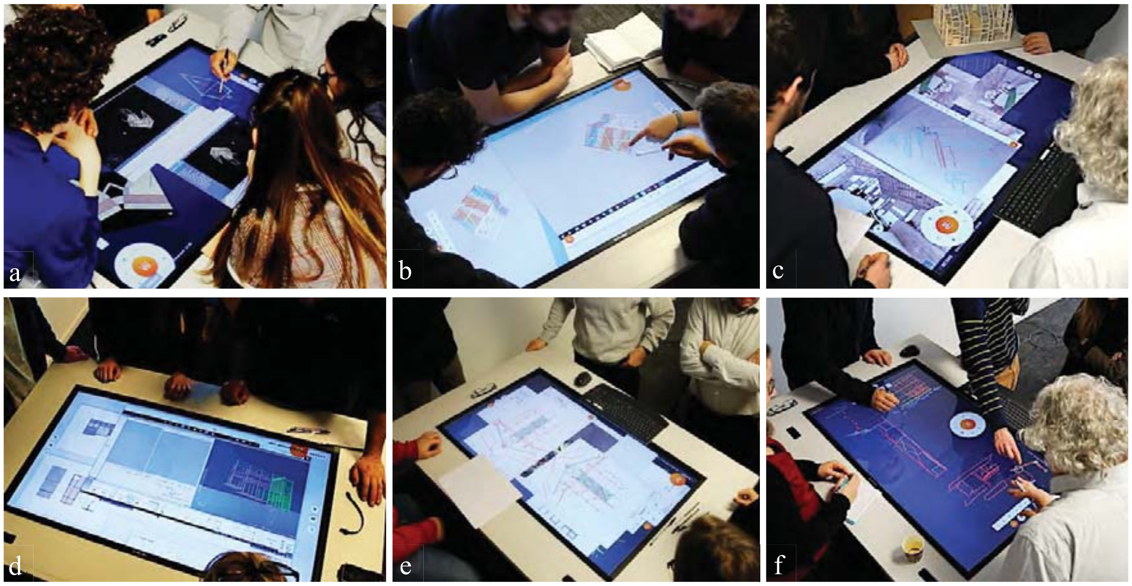

Figure 6: 2019, Examples of interactions: (a) 3D visualization and sketching on background, (b) 3D model manipulation and pointing, (c) rendered images review and sketching, (d) plans, sections, 4D simulation visualization, (e) section permanent annotations, (f) background sketching.

2.5 Research questions and Feedback collection tools

Naturally, every construction project is unique. A stakeholders team collaboration strongly depends on a project type. Their synchronous collaboration and decision-making depend on meeting types, which require specific meeting objective documents and access to group interactions. In order to design a collaboration support tool with a well-adapted to AEC users interface and collaboration method we study the use of DCT by Wood Challenge participants. With this study, we aimed to evaluate:

- Utility and usability of the digital collaboration support (i.e. interactive table & Shariiing) and to emphasize advantages and current limits of such tool through the users feedback.
- Perceived role of 3D and 4D models at discussions on the pre-construction phase

Also, for this study, with DCS observations, we aimed to better portray decision-making dynamics and main aspects, such as: time of the session, documents used for discussion, interaction gestures and decision-making point. The DCT influence on pedagogy is in the scope of the interest as well. Moreover, the experiment analysis highlights user's needs for digital documents better interactions.

The session's interactions were documented with video cameras and the table screen records. Also, participants' feedback was collected through a custom-built questionnaire and semi-guided interviews. Figure 7 resumes main feedback collection sources.

The first part of the questionnaire offered to session participants is to fill up the System Usability Scale (SUS) (Brooke, 1996) which is composed of ten traditional items to note on a Likert Scale. The scale is a free and quick tool to measure the system usability, however it provides quite reliable results to measure usability and learnability (Sauro & Lewis, 2011)(Brooke, 2013).

Accompanying the SUS scale, earlier, for feedback collection from similar digital collaboration experiments with professionals, the 4D Collab team also included open answer questions on usability. These questions allowed us to collect more complex feedback from the AEC professionals. To stay in correlation with the previous experiment records, the same questions follow the SUS part of the questionnaire for our pedagogical experiment feedback. Additional questions on 3D, 4D and planning complete this second part. The semi-guided interviews about DCT usability and requirements, specific to the AEC, complete this part of the feedback.

Also, the questionnaire for the student teams contained parts on group reflexivity (Carter & West, 1998), a Technology Acceptance Model 3 (TAM 3) (Venkatesh & Bala, 2008) and a 4D BIM uses evaluation, however their results are not covered by this paper.

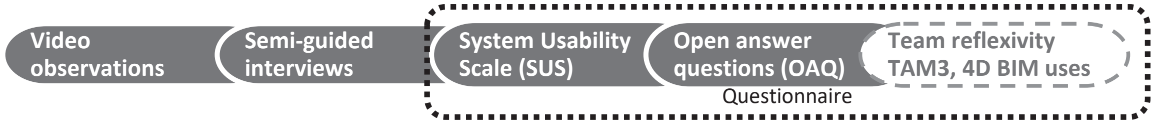

Figure 7: Summary of the feedback collection steps for the pedagogical experiment

3. Findings summary

3.1 SUS score and usability feedback

In total, we have collected a SUS from 9 users at Phase 1 in 2018, and from 29 users in 2019 at Phase 2. With two main categories of population: students and professors; and one subcategory for the students by the studies background: architects, wood and civil engineers.

The feedback for the Wood Challenge 2018 emphasized the SUS score for all users (students and professors) as a mean score of 75 points (on a scale from 0 to 100, passing range starting from 68). Thus, according to a Rating Score summarized by Bangor et al. (Bangor, Kortum, & Miller, 2009), this result would be: rated as "*good*" in adjective ratings; filling into "*acceptable*" acceptability ranges; corresponds to a letter note "C". Also, in 2018, the professors mean score of 75.83 is slightly higher than the score from the students, at 74.58, but it stays relatively close to the students and All participants (see Table 2). Regarding the study domains (subcategory), the architecture students gave a much higher score than wood structures engineers. To summarize, these scores may be interpreted that in general, 2018 users are rather pleased with Digital Collaboration Table, and find it usable and highly intuitive.

As of 2019 the mean SUS score for all users is 61.12. According to the Rating Score, this number is rated as "D", and being between "OK" and "Good" in adjective ratings. It is much lower than in 2018, and has a significant deviation. The professor result was a little higher than a year before, at 79,5, and it was very different from the student score of 56.87. The professors already had some experience with the Digital Collaboration table a year before and, even with updates, they still felt confident in the given score and positive opinion. However, in 2019 more student teams have participated at DCS than the year before, and not only those most open to innovation and digital collaboration like in 2018, which has influence on technology acceptance in general. The students also had twice as many sessions with the DCT than their predecessors, and thus had a long-term and multiple uses perspective. As before, the architecture students gave a higher score than the engineers. The scores are summarized in Table 2.

Besides the abovementioned scores by users categories, there are additional scores. Most of the participants (79% with score 69,33) have confirmed that, in general, with the DCT they could perform their actions well (with no obstacles) during collaboration sessions. As for the participants who did not say that they could execute their intentions well (score 42.5, max 47.5), they would give most often mention that session discussion is very animated and they did not have enough time (or quick enough reflexes) to quickly visualize the documents they wished to use as the discussion support. Some of them mention that they prefer to use a pen and paper for decision-making.

Besides, the active users of CAD give slightly higher SUS scores than others, but the experienced 3D model users tend to give higher scores (76) than less experienced users (55). The participants with more field experience also tend to give a higher score (76) than others with less than 2 years of experience (59,8). Despite some low SUS scores from some users, the added open questions (Section 3.2) portray a positive experience, and show again a good usability of DCT.

Table 2 Summary of SUS scores for digital collaboration table by project roles

		All participants	Students	Professors	Architects	Wood Engineers	Civil Engineers
2018	Mean Score	75	74,58	75,83	78,13	67,5	-
	Deviation	*6,96*	*8,12*	*5,2*	*4,73*	*10,60*	-
	Count	*9*	*6*	*3*	*4*	*2*	-
2019	Mean Score	61,12	56,88	79,5	59,17	56,67	53,75
	Deviation	*15,71*	*13,77*	*10,37*	*11,18*	*18,16*	*11,15*
	Count	*29*	*24*	*5*	*9*	*9*	*6*

Despite the low number of participants, we analyzed the data statistically. First, in any group larger than 8 we verified whether the score distribution was normal with two tests: Shapiro-Wilk (SW) and D'Agostino's K^2 (DAK^2). None of the scores given by architects, engineers, professors, nor all respondents together violate the normality assumption (in SW p-value ranging from 0.196 to 0.647, W from 0.94 to 0.96; in DAK^2 p-value ranging from 0.268 to 0.521, K^2 from 1.30 to 2.64). However, since normality tests are of little power on small sample sizes, for investigating the similarities and differences between the groups we did not restrict ourselves to parametric tests (T-test; whether the variance was the same or not, decided by an F-test for equal variances - always different in our case), but also carried out two non-parametric ones (Kolmogorov-Smirnov (KS) and Mann-Whitney (MW)) (Fig. 8).

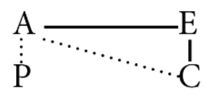

Fig. 8: the schematic representation of similar and different respondent groups by T-test, KS and MW tests: A - architects, E - engineers, C - civil engineers, P - professors. A continuous line: the scores are consistent with the hypothesis that the two groups come from the same distribution, according to all three of the tests. A disagreement between some of the tests makes it a dotted line. The absence of a line signifies that all tests reject the null hypothesis and conclude that the populations are significantly different.

The professors group, P, the highest scores, stand out from the others: their scores are statistically significantly different from those of C and E, who gave the lowest scores (p-value < 0.01 in all tests). The group that resembles P the most is the architects (A), who came out to be similar to them in the first edition of the study (p=0.580 in T-test, 0.961 in KS and 0.500 in MW test; the statistics t=0.60, F=0.33, U=5.50 respectively) and different in the second one (p-value < 0.05 in all tests, t=-3.92, F=0.80, U=1.50), bringing about mixed results when taken together (different according to T-test and MW, p<0.01, and not dissimilar according to KS, p=0.072,). The pairs A and E and C and E are consistent with the assumption that the respondents' scores come from a same population. Groups A and C are close to conforming to the similarity hypothesis but not unanimously (similar according to MW, p<0.05, U=19.00, and different according to T-test and KS, p=0.079 and 0.059, t=1.93, F=0.60).

3.2 Summary of feedback and interviews

In general, session participants (users) find the DCT very ergonomic for meetings, it unites the documents well in a single environment and allows shared views of the same document for everyone around the table. Thus, it allows better understanding, fosters collaboration, and exchanges at the meeting around the table. Also, users mention a "playful aspect" added by DCT, which creates a more informal setting for the meeting.

Regarding the document transfer at the table, users were glad to use quick wireless file drop from their laptops to the table to bring the last-minute modifications version of the document to the discussion. Some users said that digital support for the documents requires a better meeting preparation, and curiously, saw this aspect not as a disadvantage, but as an advantage which would help them to be more efficient in preparation to a meeting. However, in the beginning of meetings, when all the documents were just starting to appear on the screen, it was hard for a presentation speaker to keep everyone's attention on the same document. Thus, to keep the focus of the users, the collaboration environment should better contain the most relevant documents to the discussion.

Visualization quality is the first of the more often mentioned benefits of the DCT, especially for 3D. Many users found a large screen to be well suited for visualization of detailed large documents (plans, sections, details, etc.), especially during review in a full-screen mode. They highlight a collective aspect of the visualization and possibility to zoom-in to view details quickly.

According to the observations, the visualization of PDF files was qualified as fluid, which was very important to review project documents. But the most emphasis was given by users to the benefits for 3D models visualization on a large screen with shared views. Indeed, according to observations a 3D model was always in the center of the discussion. In addition, users were glad to be able to share their laptop screen with a 3D or 4D model opened in their modeler (Archicad, SketchUp, Cadwork, Rhino, Navisworks) directly, without needing to export to other file formats.

Accessibility of interactions with documents is the second most often mentioned benefit of the DCT. Users have noticed progress on fluidity of actions with the latest version of the software. Users appreciate being able to zoom-in on a detail and then highlight problems with temporary or permanent annotations to explain them to others, or even to annotate simultaneously with their colleagues. A manageable 3D model navigation is also mentioned by users as one of the beneficial and essential interactions.

Many suggestions on DCT improvements were about annotation and drawing functions. More than a third of the experiment participants described the current drawing precision (line thickness, touch precision) as somewhat lackluster. Therefore, they preferred to make a double of the DCT sketch on a paper for better precision. Some suggested providing users with styluses.

Since 3D models were at the heart of most of the exchanges, many user suggestions and critiques were received about 3D visualization and navigation. For example, a few users stated that it is harder for them to understand or interact with 3D models and they prefer 2D documents. They suggest replacing 3D navigation with necessary pre-set point of view screenshots, to avoid the need to navigate through the views/model. When students were sharing their screens with 3D models (in the professional software) into the Shariiing, some have noticed delays between manipulation actions (move, zoom, rotate) and model response time. Thus, a more efficient way to share screens is to be developed and a better preparation protocol of 3D model for the session, which must be run on a performant laptop, is to be identified.

The users also highlighted a difficulty of finding the right documents and also a need to stay connected to their project cloud services, to be able to have an easy access to all the documentation directly, without downloading them into the session.

The session results and feedback formalization tool and "tasks to do" before the next meeting tool were also requested to organize better the decision-making, and document decisions in a more detailed way than 2D annotated documents.

Most of the users state that 3D visualizations are useful for decision-making on design development or value engineering. They have also agreed that 4D improves understanding of planning problems and is a useful asset for a collective decision-making on scheduling or construction strategies.

3.3 Digital Collaboration Session activities

We distinguish three main levels of interactions with DCT: visualization, manipulations, and annotations. Users may visualize 2D documents, 3D or 4D models. They may manipulate the Shariiing windows with: move, pinch, and rotate. Inside the sharing windows while visualizing the documents, "zoom" manipulation is also possible, along with annotations (drawings): temporary (disappearing), and permanent.

Also, DCS participants had access to sketching on the Shariiing background table (Fig. 6f) and notebooks and pens. Naturally, users accompany their session with discussion (verbal communication), pointing, and mimicking gestures.

The major use of the DCT was visualization (Fig.6c,d), accompanied by user discussion and pointing gestures (Fig. 5a, 6b). Model manipulations were mostly used for project presentation and to fix a point of view to annotate a solution. Sketching and annotations (Fig.6a,e,f) were used to support a solution proposition and to suggest modifications, however not every session benefited from the annotation function. Since the duration of manipulations and annotations are lower than visualization, we will count these "actions" throughout the activity.

The DCS duration depended mostly on a project design and technical solutions quality. For instance, teams presenting only 2D documents, or only 3D models, or 3D and 4D models did not show a shorter time depending on the represented document types. As a main support for decision making and discussions, participants felt more inclined to use a 3D model. They also tended to solve all the questions with only one document as a decision-making support (2D or 3D) (see Fig. 10 for sources of the shared views on the models from students' laptops to Shariiing Advanced). Most of the time, a relevant decision would be made in the middle of a session, and would then be followed by additional suggestions on design or engineering. 4D models were used only in the beginning of the meeting to visualize construction sequence logics, but yet further discussion was supported by a 3D model due to better interactions.

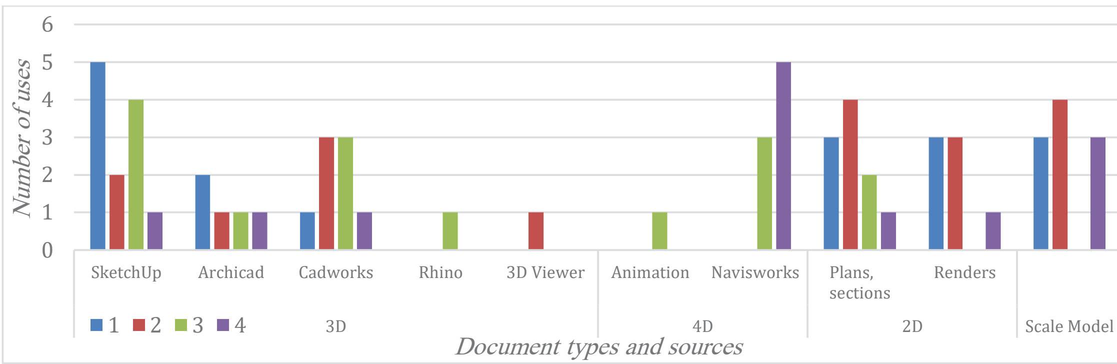

Figure 9: Information sources for Digital Collaboration Session Numbers 1-4 for Wood Challenge 2019 (shared views from laptops for 3D and 4D)

4. Conclusions

This paper summarizes the pedagogical experiment on synchronous collaboration at project review meetings with digital support (Digital Collaboration Table - DCT). The experiment context of the pedagogical exercise Wood Challenge was an opportunity to follow the collaboration of student teams and professors from the design to construction, and to assist at weekly project meetings with DCT.

Such context allowed us to evaluate DCT usability and learnability from active and frequent user perspectives in the case of a real construction project (i.e. small wooden structure). Also, the study highlighted user interactions with digital project documents during their collaboration sessions, in particular 3D and 4D model interactions. The analyzed user activities at collaboration sessions showed that 3D models are principally in the middle of the discussion, and thus must have the most fluid interactions. The DCT must provide not only the 2D annotations but also to be able to support BIM model annotations.

The Digital Collaboration Table represents a useful support for the project document's visualization, and for the document's manipulations and annotations. Also, it is a valuable support to more democratic collaboration of the project documents and to decision-making. However, user feedback suggests several categories for further improvements of the support and its adaptation to AEC project review. Among the key suggestions are: the need for a simple touch interface adapted to particular use cases for easier manipulation and annotation in 3D and 4D models; the need for automatic documentation of collaboration results and their integration into the BIM model structure; the need for an augmented sketching function for improved precision; the need for further integration of the table into a collaboration system connected to the cloud. These further improvements will be integrated into a prototype for a new collaborative 4D-based decision-making device by the 4D Collab research project team.

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