USING INTERACTIVE WORKSPACES FOR TEAM DESIGN PROJECT MEETINGS

Mohamed Issa, Mr,
University of New Brunswick
m.issa@unb.ca

Jeff Rankin, Dr,
University of New Brunswick
rankin@unb.ca

John Christian, Dr,
University of New Brunswick
jchristian@unb.ca

Evan Pemberton, Mr,
University of New Brunswick
g441z@unb.ca

ABSTRACT: An Interactive Collaboration Laboratory (ICL) has been established at the University of New Brunswick (UNB) to research the application of interactive information and communication environments for the architectural, engineering, and construction (AEC) industry. This paper provides a quick overview of the laboratory within the wider context of interactive collaborative workspaces. It identifies opportunities to enhance information communication, and group decision-making offered by the laboratory, and focuses on lessons learned to date from its use. The paper reports on a survey conducted among final year undergraduate students who used the environment over the course of three months for their senior design project meetings. A questionnaire was distributed to those students to investigate the impact of the environment upon the effectiveness of their meetings and decisions, the issues and processes where the environment was more (or less) useful, and the context within which the environment and tools were used. The questionnaire also investigated the impact of the environment and its tools upon their project, the quality of their work, and their overall satisfaction. Students found the laboratory to be specifically useful at the preliminary design stage when designing, viewing, and analyzing the site and building layouts of their projects, and determining the project's sustainability requirements, and targets. The laboratory enabled student groups to view information from different perspectives, access remote information, and save captured information instantaneously. It also enabled them to collaborate more effectively, make more educated decisions, make better use of their time, produce higher quality work, and develop among them a relationship of trust, respect and mutual understanding. Investigating how best to use the lab's technology to serve their needs, occasionally slowed down their progress and distracted them at times from focusing on their work.

KEYWORDS: Interactive Workspaces, Collaborative Environments, Information and Communication Technologies, Team Design Projects

1. INTRODUCTION

The architectural, engineering, and construction (AEC) industry is fragmented. The complex nature of construction projects, the number of project stakeholders, the diversity and complexity of their relationships and that of their respective organizations, and the large amount of information exchanged along the different phases of construction projects all complicate the decision-making process. A great deal of information needs to be communicated between participants from different organizations dealing with different phases of a construction project. Key-decisions rely on a seamless and constant flow of information. Misinterpreted, lost, incomplete and inaccurate information impede the decision-making process, and compromise the effectiveness of decisions made during the planning, design, and construction stages of civil engineering projects. The effectiveness of those decisions is also affected by the degree of collaborative working between the key-players involved. A number of key-decisions rely upon the active and simultaneous involvement of many stakeholders. Those stakeholders are expected to work together for the ultimate

benefit of the project, and its client. Every stakeholder is expected to have an input in the decision being made so that a decision that accommodates and reflects all stakeholders' perspectives can be reached.

The emergence of information and communication technologies (ICT) has played a vital role in improving information communication between participants, and enhancing collaborative relationships that develop among them during the design and construction of AEC projects. Today, a great deal of information is generated electronically. Nevertheless, the communication and exchange of information occurs manually. Project stakeholders rely in their meetings on paper-based information that do not enable them to share information, make and capture changes instantaneously, and document information generated collectively. There is a need therefore for an environment that removes physical barriers, and allows information to flow electronically in a seamless manner. Information needs to be generated, communicated, and received without getting lost, delayed, or stopped along the way.

Interactive workspaces present an opportunity for that type of environments. Interactive workspaces or interactive environments are "technologically enhanced project rooms that are used to solve problems and make decisions collaboratively" (Johanson et al. 2004). These environments usually use, and rely upon sophisticated ICT as part of their infrastructure to enable participants to communicate, and collaborate together, work on their problems, generate solutions, and thus improve the quality of their group decisions. They offer a more effective alternative to traditional paper-based environments. Current research work focuses on investigating the application of those environments to various AEC scenarios and meetings (Golparvar Fard et al. 2006, Gopinath et al. 2004, Messner et al. 2005, Rankin et al. 2006, and Yerrapathruni et al. 2003).

The Interactive Collaboration laboratory (ICL) was initially established at the University of New Brunswick (UNB) since September 2005 for that same purpose. It has been used primarily by the Construction Engineering and Management Group in the department of Civil Engineering, and practitioners in the Atlantic Canadian region. Its use has been progressively on the rise to include academics from other research groups within the department, other departments within UNB, and undergraduate civil engineering students.

This study reviews the general characteristics of interactive environments, and provides a quick overview of the ICL. It identifies opportunities offered by those environments to improve information communication and decision-making, and focuses on lessons learned to date from their use. Also the study reports and reviews the results of a survey conducted among final year undergraduate students in civil engineering at UNB who used the ICL over a 3 month period for their senior design projects. The questionnaire was designed to help students assess the relative usefulness of the laboratory and its tools for their particular needs, and the challenges they faced when using that environment for the first time.

2. INTERACTIVE WORKSPACES

This section will focus on exploring the general characteristics of interactive workspaces, and identifying opportunities to improve the decision making process in those environments. The section will also introduce the Interactive Collaboration Laboratory (ICL), located at UNB and used to host this study's design project meetings.

2.1 Defining Characteristics

Interactive workspaces usually contain state-of-the-art technology that enables stakeholders to collaborate, and share, communicate, and interact with information more effectively (Rankin et al. 2006). Meetings conducted within those environments are believed to be more productive than traditional meetings (Golparvar Fard et al. 2006). Documents stored on computers available in the room can usually be projected and viewed electronically on large touch-screen displays. Those computers are usually connected to a server computer on which important files and folders are stored. The contents of this server computer can be accessed from any of the remote computers, and viewed on any of the touch-screen displays available in the room. This setup enables users of the room to follow through documents collectively, make and capture changes electronically, and agree on interim decisions without ever having to leave the room, or bring hard copies of those documents with them. The wireless infrastructure of the room enables users to access information online, and share the content of their personal computers with other members of the group by displaying it on one of those big screens (Rankin et al. 2006).

Interactive environments should support electronic documentation and collaborative learning and allow team members to bring in less paper-based information with them to meetings (Rankin et al. 2006). They should enable stakeholders to participate and join in group discussions; express their opinions and concerns, and access

information in a more relaxed, flexible, and friendly environment. They should also allow them to communicate more effectively with each other, thus rendering their interaction less prone to misunderstandings, loss, or misinterpretation of information. The environment should give stakeholders the opportunity to make decisions on a collaborative and consensual basis, and capture these decisions electronically after being approved by each and every member of the group (Rankin et al. 2006).

Interactive workspaces, or collaborative environments, usually contain permanent and portable computational devices (Johanson et al. 2004). Permanent devices include touch-screen boards, mainframes, and input-output devices such as wireless keyboards, and laser pointers. Portable devices include personal laptops and personal digital assistants brought in temporarily by users of the room. Touch-screen boards are usually large enough so that they can be viewed from every angle, and controlled from anywhere in the room. Users can control the display on the screen by direct touch, using digital pens, or using wireless input devices such as wireless keyboards, and laser pointers. Some boards allow multiple simultaneous controls by giving two or more users the ability to interact with the display at the same time, and from any location within the room (Fox et al. 2002). Video and audio capture devices are also usually used to capture, and record users' interaction inside the environment (Burris 2005).

2.2 Opportunities for Improvement

Fig. 1 presents a model that aims to identify issues in the group decision-making process that could be enhanced through the use of interactive workspaces.

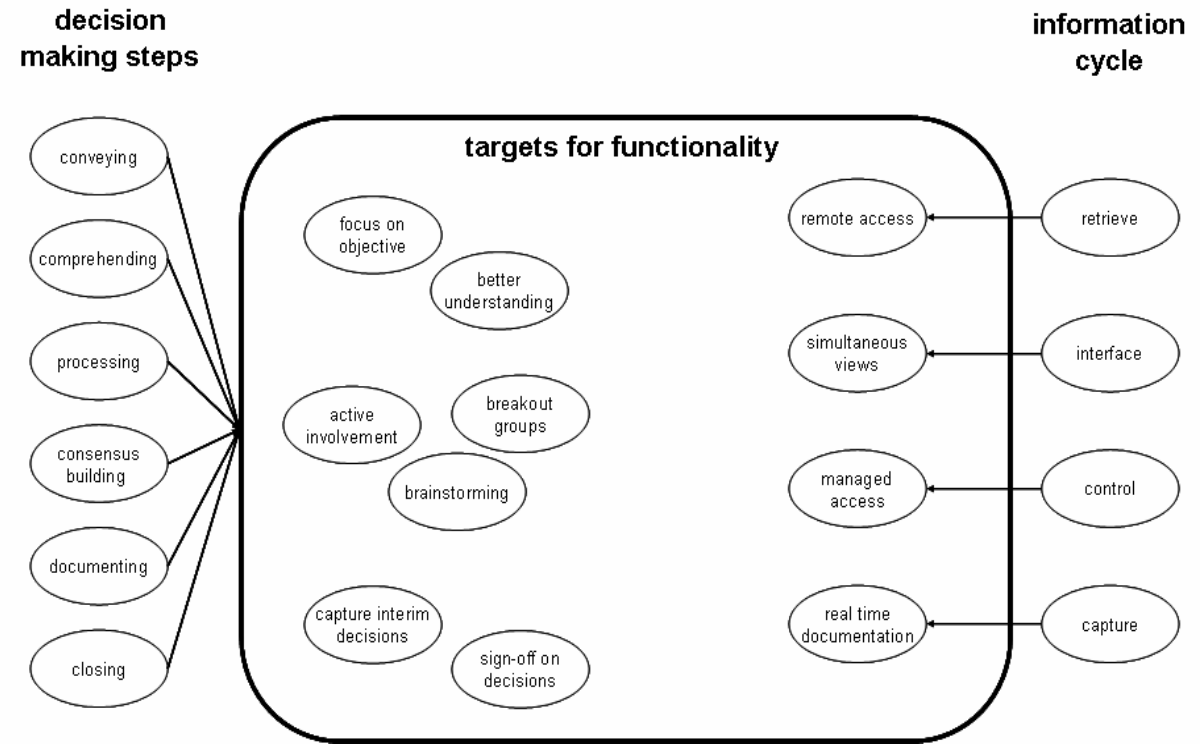

Fig. 1: Opportunities for group decision-making improvements in interactive workspaces

The leftmost side of the model identifies from an information perspective, specific group decision making steps that could be enhanced through the use of interactive workspaces. The rightmost side of the model identifies opportunities for improvement in the information cycle: opportunities in retrieving, interacting, controlling, and saving information. The center focuses on identifying for every issue raised on both sides of the model specific targets for functionality: specific needs that interactive workspaces will need to meet in order to improve information communication and users' collaboration. Those needs, if met, should enhance every step of the group decision-making process in the leftmost side of the model, and should ensure the full completion of the information cycle on its rightmost side.

2.3 The Interactive Collaboration Laboratory

Examples of interactive workspaces used in the AEC academic field include the Interactive Room at Stanford University, the Immersive Environments Laboratory at Penn State University, the State of the Art Interactive Workspace at the University of British Columbia, and the Interactive Collaboration Laboratory (ICL) at the University of New Brunswick (UNB). These environments have proven to be successful since their inception, and have been used in different ways to cater for the different needs of the wide variety of professionals, and academics in the AEC field.

The Interactive Collaboration Laboratory (ICL), the most recent of these aims to provide a comprehensive, flexible, and interactive environment in which practitioners of the industry, and university academics are able to hold meetings, discuss problems, make decisions, and improve the execution, planning, and management of their AEC projects. Opened in September 2005, the laboratory features two 72 inch rear projection wall mounted interactive boards with projectors and peripherals, one 60 inch mobile rear projection interactive board with an integrated projector and mobile cabinet, one 46 inch interactive tabletop display, and one high-end resolution surveillance camera. The boards are touch-screen rear-projection boards developed by Smart Technologies Inc. These boards act as large size regular computer screens. The two wall-mounted boards can be connected together to act as one larger board. The boards can also be used as regular whiteboards. The digital special pens (four coloured pens for each board) included in the Smart pen tray together with the Smart eraser enable users to write digitally over the whiteboard, and thus capture information instantaneously. These boards also respond to direct user touch: users can use their fingers to control the display. For instance, they can tap on the board instead of clicking on the mouse, thereby facilitating tasks such as selecting and deselecting words, or minimizing and maximizing windows. A wireless slate, with a wireless mouse can also be used from anywhere in the room to perform those same tasks. Every board has its own remote control, with a laser pointer, that enables users to control the screen display's properties and settings. The room also incorporates a room server, a wireless infrastructure, and leading software applications to support the management of AEC projects.

The wireless infrastructure in the ICL provides the user with remote access to other desktops and laptops while in the laboratory and with wireless internet access that enables users to connect to the World Wide Web. Every board is connected to a private computer, and the three computers are all connected to a private server on the UNB network. This server is used to run its own applications as well as manage information within the ICL. The files on the server can be accessed from any of the three other remote computers. The two wall-mounted boards can also be connected together to act as one single larger board.

The ICL aims to provide a comfortable seating environment for its users. It is equipped with a 12 seat boardroom table. The large table can be divided into three smaller trapezoidal tables to allow users to break down into smaller groups if they need to do so. Fig. 2 presents a schematic of the ICL.

The ICL was established by the Construction Engineering and Management Group in the Department of Civil Engineering at the University of New Brunswick (UNB), and has been controlled, managed, and used by this Group since its inception. The ICL is primarily for the exploration of the adoption and implementation of interactive collaborative technologies to the AEC industry. Graduate courses in Construction Engineering and Management are usually taught in the laboratory. The Group's general biweekly meetings, in which professors, graduate students and researchers in the group meet also, take place inside the laboratory. Fig. 3 shows graduate students and faculty members in the Construction Engineering and Management Group at UNB using the ICL for one of those meetings.

The ICL is also used for meetings of the Construction Technology Centre Atlantic (CTCA): a non-profit research organization located at UNB, and aimed at increasing awareness and access to the latest technological advances in construction management in Atlantic Canada. The ICL also provides the technology infrastructure required to an ongoing two-year technology transfer project funded by the National Research Council's Industrial Research Assistance Program and delivered by CTCA to promote the use of such technologies to the AEC industry. It was not until the start of 2007 that the laboratory opened its doors for the first time to undergraduate students in the Department of Civil Engineering.

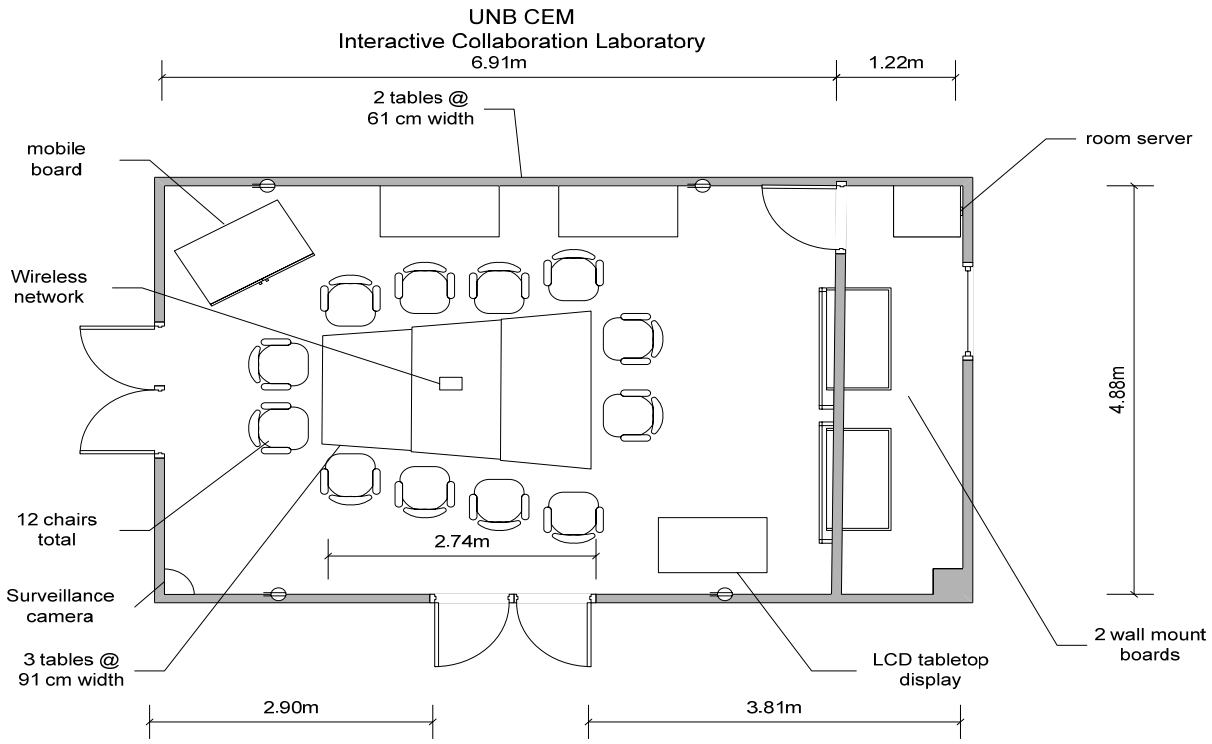

Fig. 2: Schematic of the ICL

Fig. 3: Construction Engineering and Management students and faculty members using the ICL

3. SURVEY TO ASSESS THE ICL

This section gives a brief overview of the design project civil engineering students worked on recently, and of the survey administered to them by the end of the term. It also presents the results of the survey, and offers a thorough analysis and discussion of them.

3.1 Design Project Investigated

The survey was administered to final year civil engineering undergraduate students who used the ICL for some of their design project meetings. Working in groups of 5 to 6, students were expected to undertake and investigate a real-life engineering design project that drew on their past knowledge, skills, and experience. They were required to manage their projects professionally, complete a comprehensive project report, and present their projects orally to the client.

The project was that of designing a new environmentally friendly office building in the city of Fredericton, New Brunswick for Jacques Whitford, an environmental engineering and consultancy firm. The office was to be designed on the existing company's site to accommodate the company's growing business and space needs. The client wanted a new building that would provide its users with standard office space, a laboratory, a warehouse, and a company vehicle compound, and ensure sufficient parking space for 90 employees, and 10 guests or visitors. The client also requested that the facility be built according to Leadership in Energy and Environmental Design (LEED) standards, and achieve a corresponding Silver rating.

Students were required to complete a complete preliminary design of the building and its site. This included designing the layout of the new building and site, designing the building's steel structure, concrete footings, and surrounding outdoor space, and site design along the Saint John River to protect it from flooding. Students were also required to evaluate the building and the site from a green perspective, and decide on the specific LEED credits, and points this building would need to meet in order to achieve the required LEED Silver rating. They were also expected to provide a preliminary estimate of the total cost of constructing this new facility.

To facilitate students' meeting, interaction, and collaboration, course instructors offered students the opportunity to use the ICL for a minimum of 2 hours per week for the whole duration of the term (11 weeks in total approximately).

3.2 Survey and Questionnaire Design

The questionnaire was administered after the release of students' final grades for the course. Out of the 5 different project teams available (27 students in total), only 4 (22 students) had used the ICL, and could therefore be surveyed. The questionnaire was administered to those 22 students by email. Students were asked to complete the questionnaire electronically, save their responses and send them back by email without divulging their identities on the questionnaire itself. The survey comprised a cover letter introducing the study to the students, and the actual questionnaire which students were expected to complete. Before administering the survey, a pilot study was conducted among members of the CEM Group to enquire about the clarity, length, accuracy, and effectiveness of the questions asked. Based on feedback received from this pilot study, the questionnaire was shortened, and a few questions were reworded to make them clearer and easier to understand to students completing the questionnaire.

The survey administered to undergraduate students who have used the laboratory for their senior design projects, is based primarily on the model defined and presented in Fig.1. This questionnaire aimed to assess the usefulness of the ICL to its users, and the impact of such an environment on group meetings conducted within it. It also aimed to particularly assess whether the ICL met the targets for functionality defined in the model, and thus whether the environment enabled its users to take full advantage of all potential opportunities to enhance the group decision-making process. To achieve those goals, the questionnaire enquired about respondents' usage patterns of the ICL, and their perception of the work environment, their individual performance, and that of their group when working in an environment like that of the ICL. The questionnaire also enquired about different aspects of information communication, collaborative working, and about the potential technical, technological, and organizational barriers to using this environment. Students were also asked to rank features and tools of the ICL in terms of their important and usefulness, and rank design activities in terms of which activity would benefit most from an environment like that of the ICL.

The questionnaire in its final format included 17 questions: mostly opinion questions that aimed to study students' perception of the ICL. It made use of several types and formats of questions: closed-ended questions in the form of checklists, likert scales, rankings, and one open-ended question at the end of the questionnaire. Closed-ended questions were deemed more appropriate than open-ended questions for this specific questionnaire because they were quicker to answer, simpler to deal with, and more suited for this particular sample of respondents with limited knowledge of the theory behind the topic investigated. To avoid the shortcomings of closed-ended questions, and give students the opportunity to express views not covered by previous closed-ended questions, one optional final

open-ended question was added to the questionnaire. This optional general question simply asked respondents to add any further details about their experience of using the ICL, and about their perception of this work environment. Table 1 shows a summary of the design and content of the survey.

Table 1: Design and content of questionnaire

Question(s) number(s) and type(s)	Issue(s) tackled/ investigated
Questions 1-3: Checklist	Usage patterns (total number of hours, frequency of meetings, etc…)
Question 4: Likert scales (7 statements)	Aspects of information communication in the ICL
Question 5: Likert scales (16 statements)	Aspects of collaborative working in the ICL
Question 6: Likert scales (8 statements)	Impact of the ICL environment as a whole
Question 7: Likert scales (9 statements)	Potential barriers to using the ICL
Question 8-10: Ranking	Features of the ICL, and devices used in the ICL
Question 11-12: Likert scales (4 statements), Ranking	Usefulness of the ICL for different general, and project specific design activities
Question 13-14: Checklist	Usage patterns of ICL's boards
Question 15-16: Checklist	Usage of environment(s) similar to the ICL (past and future usage)
Question 17: Open question (optional)	General comments about experience of using the ICL

3.3 Survey Results and Discussion

15 out of 22 (68%) students responded to the questionnaire. Out of those surveyed, 46% used the ICL between 20 to 30 hours in total, meeting between 2 and 3 hours every week.

Fig. 4 shows students' responses to a survey question asking them to assess different aspects of information communication in the ICL. 80% of students agreed that the ICL environment improved information communication within their group. More than 90% of students found that information rarely got lost or misinterpreted during their meetings in the ICL. 73% of them felt that conveying information was easier in the ICL. A similar proportion of students also believed that documenting and capturing new information was easier in the ICL. Nevertheless, 60% of all students were unsure about whether the ICL facilitated access and retrieval of information.

There are a few possible theoretical explanations as to why the majority of respondents did not find access and retrieval of information, in particular, easier in the ICL. Students might have not had the opportunity to explore the environment from that side: they might have used the environment to document, capture, and save new information rather that search for it. They might have also relied on traditional storage devices (hard disks, CDs, memory cards etc…) for the storage and retrieval of documents instead of storing and retrieving all their documents from a web-based document management system, or from the server computer located in the ICL. Future research needs therefore to investigate those theories further.

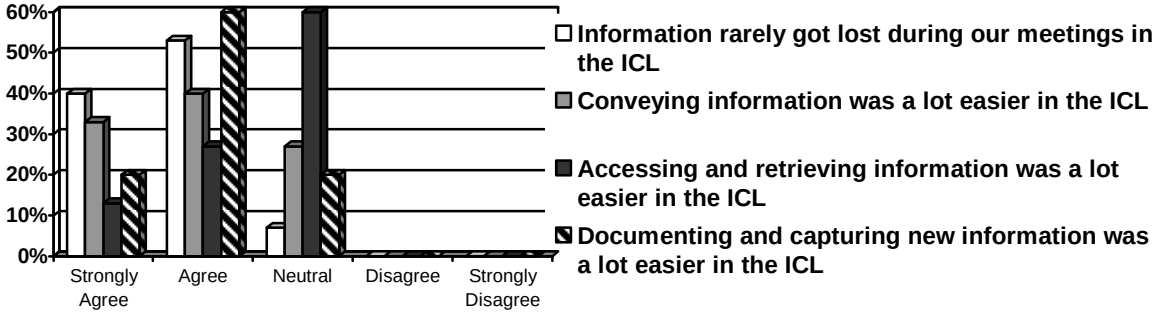

Fig. 2: Students' perception of different aspects of information communication in the ICL

Even though students' responses remained positive, students seemed less likely to fully agree with some of the stated benefits to collaborative working when using the ICL. 93% of students believed the ICL environment improved collaboration within their groups. Only 60% of students felt more focused on their work priorities when in the ICL. 13% of them thought it was more difficult for them to express their opinions and be heard in the ICL. A similar percentage of students also felt that meetings progressed slower in the ICL, and did not always go as planned. Only 40% thought work conducted in the ICL was of higher quality whereas 67% of all students believed they were more productive as a group in the ICL. Fig. 5 summarizes some of those results.

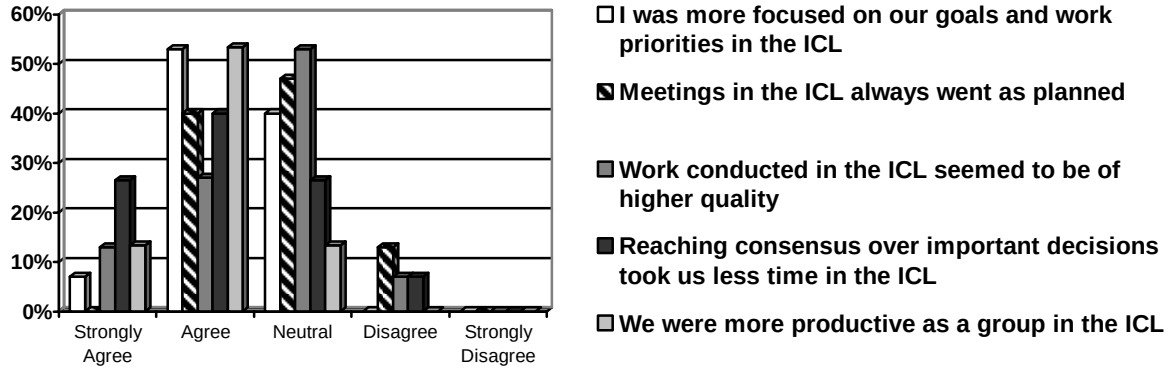

Fig. 3: Students' perception of different aspects of collaboration in the ICL

It was interesting to note that a tiny minority believed it was more difficult for them to be heard, and express their opinions in the ICL, and that meetings progressed slower, and did not always go as planned in the laboratory. Even though the survey does not investigate the underlying reasons behind those perceptions, a few speculations as to why this is the case, can be made. Those students might have found the environment to be overwhelming with its technology, and might have therefore felt more comfortable expressing themselves and getting their ideas across in a more traditional, familiar setting. They might have also felt distracted at times by the environment's tools, features, and setting, and might have had therefore to work at a slower pace in response to those distractions.

With regards to barriers, and disadvantages to using the ICL, 33% of students felt they had lost a lot of time initially in order to learn how to use the ICL's technology. An equal number of students believed that the ICL's technology was quite advanced for their needs. 47% of all students were also unsure at times how the ICL's technology would be useful for their particular needs, and 20% of them admitted that the focus on the technology occasionally prevented them from focusing on their work. Only 6% did not feel comfortable using the ICL's technology on their own, and a similar percentage of students felt frustrated with the technology's occasional glitches. Fig. 6 represents some of those results graphically.

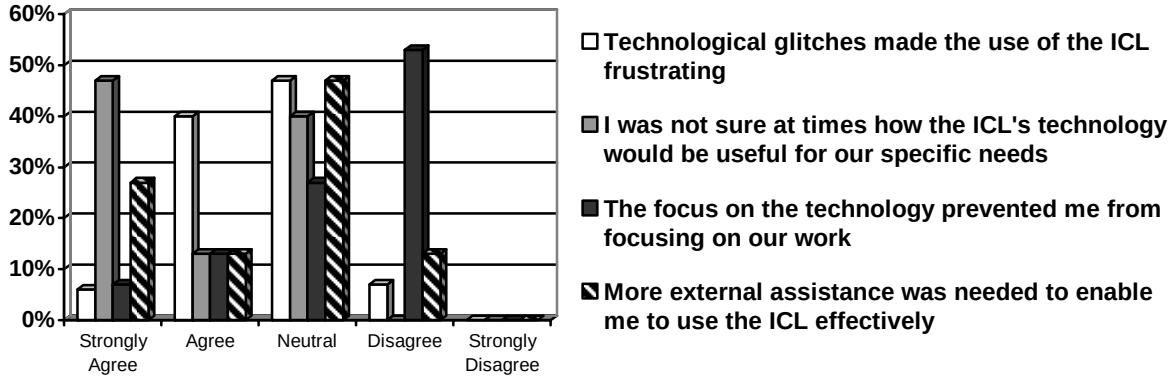

Fig. 4: Students' perception of barriers to using the ICL

The question asking students to rank the 5 input devices available in the ICL in terms of their usefulness produced surprising results. As can be seen in Fig. 7, 46% of students believed that digital colored pens were the most important input device available in the ICL: more important than other input devices such as wireless keyboards.

This seems pretty surprising given the importance computer users accord to keyboards in general. Nevertheless, it shows the importance of digital pens in capturing new information in a group setting when using touch screen boards. Surprisingly, the wireless slate with pen, and the wireless mouse ranked very low even though the pen and mouse could be used on the slate from a distance to enter and manipulate information. Nevertheless, this result is in line with feedback received from previous people who have used the pen attached to the slate to enter information and found this input device to be generally cumbersome, and impractical. Students might have also found the separate wireless mouse unessential because the wireless keyboard itself embeds a trackball and two buttons that could be used like a regular mouse.

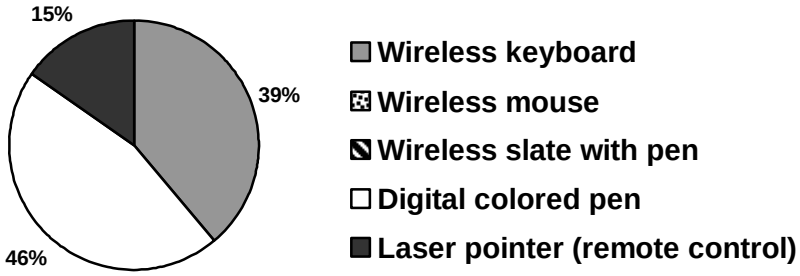

Fig. 5: Most useful input devices in the ICL

Fig. 8 represents students' opinions about design activities for which the ICL would be most useful. An overwhelming majority of students (72%) agreed that the ICL would be most useful for investigating buildings and sites layouts. This finding is hardly surprising since there are many advantages to conducting this activity in an environment like that of the ICL: users can project those layouts and drawings on large high-resolution displays, and interact, modify, and visualize those layouts in 3 dimensions collaboratively.

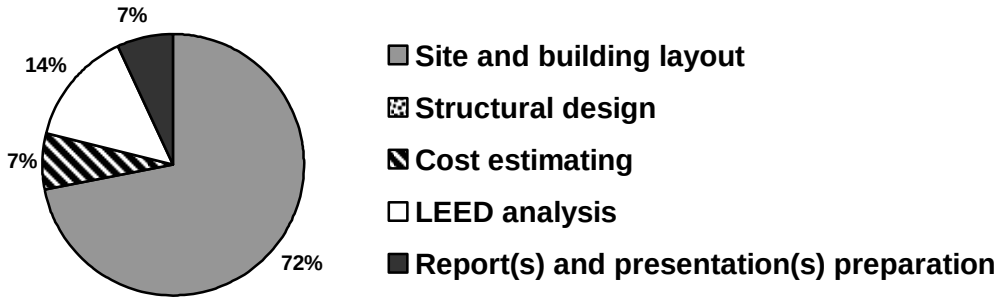

Fig. 6: Design activity for which the ICL would be the most useful

Quite surprisingly, results in Fig. 9 show that approximately half of all students consider "the ability to share the same set of data with users of the room on a large display" the most important feature of the ICL and consider other more sophisticated features of the ICL less important. While students' responses for this question should not be disputed, it is essential to note nevertheless that the way the statements of the question were worded, could have produced biased results. While the statement "the ability to share the same set of data with users of the room on a large display" emphasizes the group aspect of the feature, other statements do not do so even though the group aspect of those features is part of what makes them attractive in interactive workspaces. To avoid biased responses, the feature: "the ability to make and capture changes made to documents instantaneously" should have therefore been worded as "the ability to make and capture changes made to documents instantaneously on a collective basis". Similarly, "The ability to access remote information" should have also been expressed as "the ability to access remote information on a collective basis". These modifications and changes would have placed an equal emphasis on the collective aspect of every feature. They would have probably therefore produced fairer, more accurate, and less biased results.

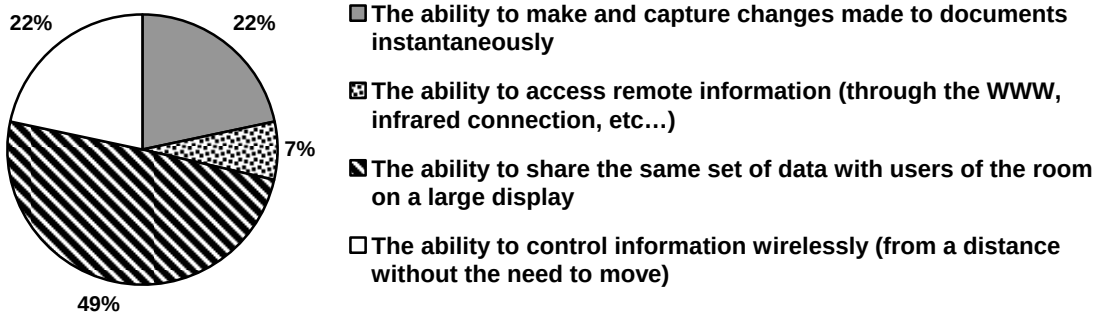

Fig. 7: Most important feature of the ICL

As shown in Fig. 10, students estimated on average that 70% of information exchanged during their meetings in the ICL was retrieved electronically through the World Wide Web, hard disks available in the ICL's computers, CDs and memory sticks brought in by users, etc… whereas 30% of the information was accessed through conventional manual means (hard copies of documents brought in by users of the room). Even though this finding clearly indicates that most of information access, retrieval, exchange, and receipt in interactive workspaces occur electronically, it would still be interesting to study whether those values change over a series of meetings as users of interactive workspaces become more accustomed to using them. It would also be interesting to investigate whether all information access, retrieval, exchange, and receipt in interactive workspace could at one point occur electronically, and whether paper-based information could ever be completely eliminated.

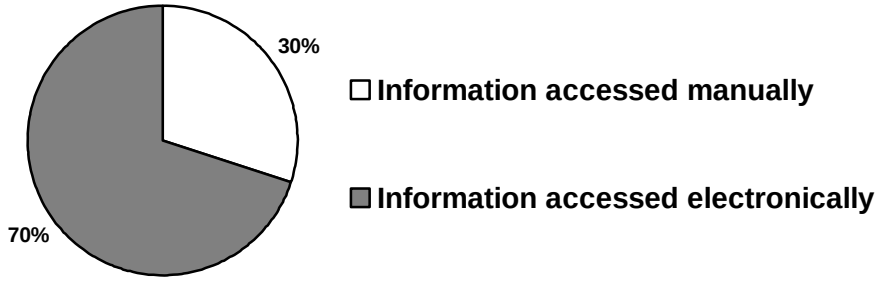

Fig. 8: Percentage of information accessed manually versus electronically

In terms of boards' usage, 86% of all students preferred using ICL2 (refer to Fig. 11 for identification of the boards). The remaining 14% favoured using ICL1. Even though the survey did not try to investigate why students felt this way, previous use and observations of students using the ICL showed that students encountered several technical problems when using ICL1. The computer attached to the board failed to detect the wireless internet network on several occasions. The wireless sensor of this same board also failed to detect the signal from the wireless keyboards a few other times. The lighting in the room also produced a glare on that particular board that made its use uncomfortable from several angles. Students might have also preferred using ICL 2 because of its bigger size, and because of their ability to use the two wall-mounted boards together as one single one when that specific board was activated.

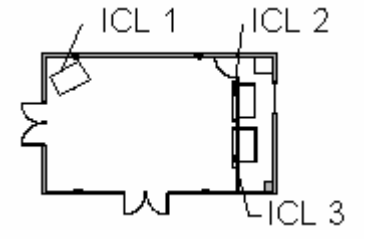

Fig. 9: ICL boards identification

Fischer's (2000) categorization of decision-making tasks was used to assess the usefulness of the ICL for different tasks types. As shown in Fig. 12, 67% of students found the ICL very useful for descriptive tasks. A slightly smaller majority of students (53%) found the ICL equally useful for explanative tasks. 33 and 20% of students agreed that the ICL was very useful for evaluative and predictive tasks respectively. While there appears to be less agreement on the usefulness of the ICL for evaluative and predictive tasks (probably because of the relative difficulty of conducting those tasks in comparison with descriptive and explanative tasks), students seem to realize the value of the ICL for evaluative and predictive ones. Those tasks are essential tasks that have a considerable positive impact upon the effectiveness of group decisions. They need therefore an appropriate setting, environment, and tools that would support them.

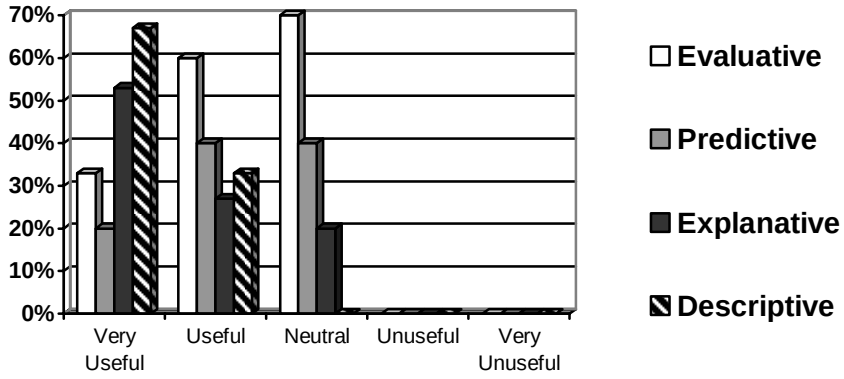

Fig. 10: Usefulness of the ICL for different types of decision-making tasks

4. CONCLUSIONS AND FUTURE DIRECTIONS

The significance of this survey is that it reflects the experiences of first-time users of an interactive workspace for design project meetings. The survey assesses different aspects of information communication, and collaborative working when meeting in this environment, and investigates some of the technical, technological, and organizational barriers to effective use of this workspace. The survey also identifies the design activities for which an interactive workspace would be most useful, and categorizes features of the workspace in terms of their importance to first-time users. It also compares between the amounts of information accessed electronically and manually in the workspace. The survey also analyzes input devices in terms of their usefulness to those users, and analyzes trends in ICT tools' usage.

Despite their numerous perceived advantages, interactive workspaces, just like ICT tools, continue to be adopted and implemented slowly and cautionally more so among practitioners than among academics. This is because ICT tools remain a costly investment that small and medium sized construction companies are unable to afford and justify. Furthermore, a clear proven framework that identifies opportunities for efficient use of those tools, and measures their specific impact on the effectiveness of group-decisions and related processes, does not fully exist yet.

That is why meetings of graduating students using the ICL in future terms will continue to be analyzed in the same way, and using the same survey. A framework will also be developed to assess more complex real-life AEC meetings in the ICL and in other interactive workspaces, and measure the effectiveness of group decisions made in those meetings using those environments.

Efforts are also on-going to apply lessons learned in this laboratory to develop solutions for more extensive academic and industry applications. On the technology front, the next focus will be on improving the transfer of information to and from the ICL through the application of high band width extensions, where applications of user controlled light paths in combination with web services in a service-oriented architecture, are being explored with the National Research Council Institute for Information Technology. On the academic front, the next focus will be on developing a proposal for a design studio that would be aimed specifically at undergraduate students working on thesis design projects, and therefore would address their specific needs. On the industrial front, more industry partners will be invited to use the laboratory for a number of design, planning and control of building and infrastructure project scenarios: it is hoped that the observation, and analysis of those meetings would give deeper

insight into the dynamics of group decisions made within the ICL, and eventually lead towards developing a solution that would assess and measure the effectiveness of group decisions made inside the laboratory.

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