# LESSONS LEARNED FROM THE USE OF INTERACTIVE WORKSPACES FOR STUDENT TEAM DESIGN PROJECT MEETINGS

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*SUMMARY: 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 senior year undergraduate students who used the environment over the course of three months for their senior design project meetings. A questionnaire was administered to those students to investigate the relative 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 relative value and usefulness of the environment for the team's needs. Students found the laboratory to be conducive to learning and collaboration. The environment was effective in preventing loss of information, and information representation. It increased participation, and encouraged decision-making by consensus. Students found it useful in explaining and presenting information to others, and in promoting greater understanding among members of the team. They also felt that the technology was easy to use and operate, requiring minimal external assistance. Nevertheless, they were not always sure about how available technology could be used to improve their work. The environment also seemed less effective in improving work productivity and decision-making. There was less agreement on the speed with which meetings progressed, and the extent to which meeting agendas were followed. It was also less effective in facilitating the access, retrieval and capture of information. The environment was more prohibitive in terms of individual expression. It was also less useful in generating and developing new information and in predicting the impact of changes on interim decisions. While results might vary from one user group to another and from one meeting scenario to another, it is imperative that additional tools and techniques are provided to address those imperfections for that particular group of users and that particular meeting purpose.*

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

## 1. INTRODUCTION

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 contribute to a challenging decision making environment. 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 collaboration between the players involved. A number of key-decisions rely upon the active and simultaneous involvement of many disparate stakeholders with the expectation they work together for the ultimate benefit of the project, and its client.

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 architectural, engineering, and construction (AEC) projects. Today, a great deal of information is generated electronically. Nevertheless, the communication and exchange of information occurs manually. For example, in project related meetings, stakeholders rely on paper-based information that hampers sharing of information, making and capturing changes, and documenting information generated collectively. There is a need for an environment that removes physical barriers, and allows information (generated, communicated, and received) to flow electronically in a seamless manner 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 typically 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 (Fard et al, 2006, Gopinath et al, 2004, Messner et al, 2005, Rankin et al, 2006, and Yerrapathruni et al, 2003).

This paper reports on an investigation of using interactive workspaces in general, and the Interactive Collaboration Laboratory (ICL) in particular, to support senior undergraduate civil engineering students in completing a team design project. The Interactive Collaboration laboratory (ICL) is an interactive workspace established by the Construction Engineering and Management Group in the department of Civil Engineering at the University of New Brunswick (UNB) in partnership with practitioners in the Atlantic Region. A study assessed the relative value of this environment to that specific group of people, and for that specific type of project, as part of a larger, more comprehensive study that aims to examine the use of the environment by different groups of people, and for different purposes. The paper first presents a review of the general characteristics of interactive environments, and identifies opportunities offered by those environments to improve information communication and decision-making. An overview of the ICL: its history, goal, and uses to date, is then provided. The results of a survey conducted with the team design students who used the ICL over a 3 month period provides the context for identifying lessons learned for this particular group.

The survey was designed to help students, and other groups of people (e.g., practitioners, academics) to assess the relative usefulness of the environment and its tools for their particular needs. The study should be of interest to academics, researchers, and practitioners who are considering using interactive workspaces for their meetings. The study should help researchers identify features of interactive workspaces that need to be brought to light or improved. It should also help researchers address imperfections in the current setup of interactive workspaces by identifying opportunities for improvements in the infrastructure of those workspaces and in the decision-making and collaborative working techniques adopted by users of those environments.

## 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 for the intended purpose of enabling stakeholders to collaborate, 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 (Fard 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).

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).

## 2.2 Opportunities for Improvement

Fig. 1 presents a model to reflect the intended functionality offered by the ICL. When setup, the ICL was intended to support a generic decision making process with a complete information management cycle in mind.

The leftmost side of the model identifies specific group decision making steps that could be enhanced through the use of interactive workspaces from an information perspective. The rightmost side of the model identifies opportunities for improvement in the information cycle: opportunities in retrieving, interacting, controlling, and saving information. The center identifies 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 management 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 ICL at UNB. These environments have proven to be successful since their inception, and have been used in different ways to cater to the different needs of the wide variety of practitioners, and academics in the AEC field.

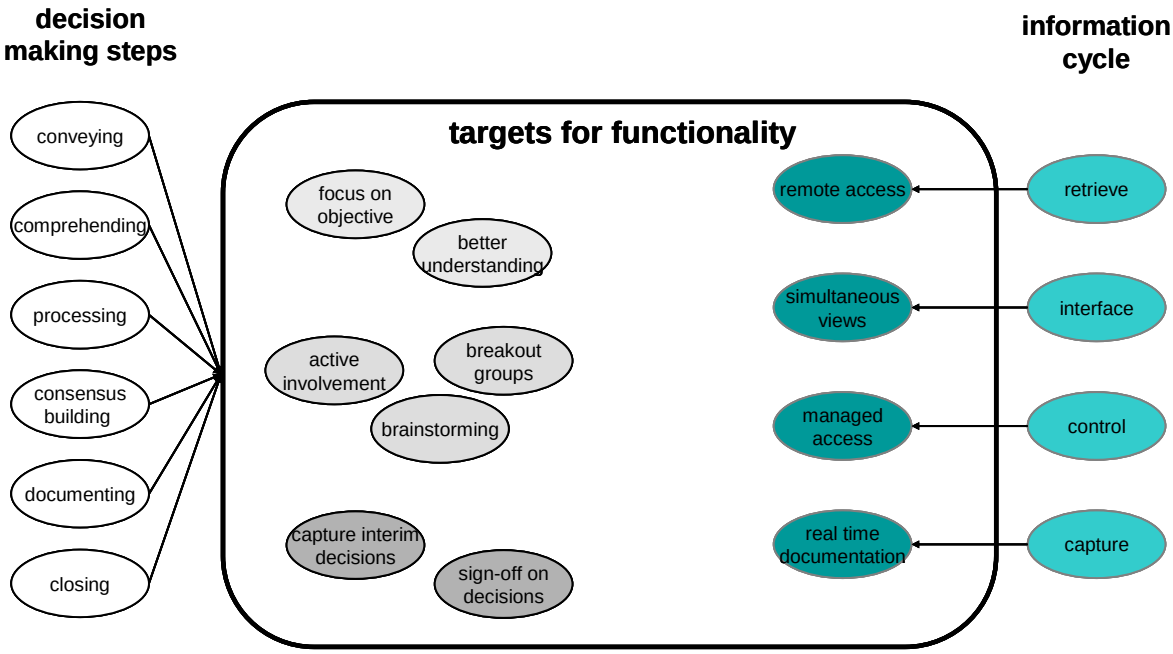


*Fig. 1: Opportunities for group decision-making improvements in interactive workspaces*

The Interactive Collaboration Laboratory (ICL) 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. Initially intended to act as an immersive environment that would support virtual reality applications, the ICL became instead an interactive collaborative environment that supports interactive collaborative meetings and applications. Established 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. They 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. Fig. 2 shows from left to right the mobile interactive display, the two larger fixed wall-mounted displays, and the tabletop display currently in use in the ICL.

*Fig. 2: (From left to right) the mobile interactive board, the two fixed wall-mounted boards, and the tabletop board currently used in the ICL*

The wireless infrastructure of 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 breakout into smaller groups if they need to do so. Fig. 3 presents a schematic of the ICL, while Fig. 4 shows a few of the different possible seating arrangements in the ICL.

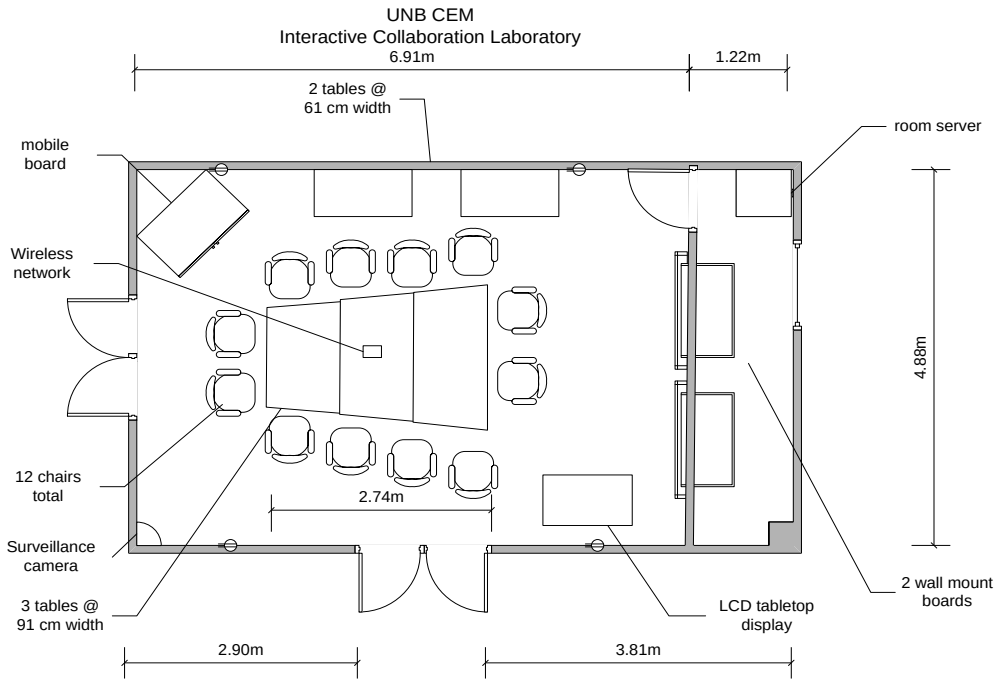


*Fig. 3: Schematic of the ICL*

*Fig. 4: Possible seating arrangements in 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) in partnership with regional industry members, and has been controlled, managed, and used by this Group since its inception. A key partner in the exploration of this technology is the Construction Technology Centre Atlantic (CTCA): a non for profit technology transfer organization located at UNB, and aimed at brokering innovation and increasing awareness and access to the latest technological advances in construction management in Atlantic Canada. Fig. 5 shows members of the CTCA industry group using the ICL for one of those meetings.

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. Graduate courses in Construction Engineering and Management are often 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. 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.


*Figure 5: the CTCA industry group meeting in 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 at the end of the term. It also presents the results of the survey followed by a discussion of each aspect examined.

## 3.1 Design Project Investigated

The voluntary and anonymous survey was administered to senior year civil engineering undergraduate students who used the ICL for design project meetings. Working in groups of 5 to 6, students were expected to undertake and investigate an actual 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 involved the design of a new environmentally friendly office building in the city of Fredericton, New Brunswick for Jacques Whitford Limited, 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 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, 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 (13 weeks in total).

## 3.2 Survey and Questionnaire Design

The questionnaire was administered after the release of students' final grades for the course. Out of the 5 project teams (27 students in total), only 4 (22 students) had used the ICL, and could therefore be surveyed. The voluntary and anonymous survey 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. 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 Construction Engineering and Management Group to check 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 for 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. It is important to note that the objective of the questionnaire was not to make the case for the use of the ICL and similar environments, or compare meetings in interactive environments to meetings in traditional environments since that type of work had already been conducted in the past. Instead, the questionnaire intended to assess the specific relative value added to students from using that environment, and the degree to which the environment met its intended purpose and targets for functionality defined in the model. It aimed to assess the impact of that environment upon the effectiveness of group meetings, and the degree to which the environment enabled students to enhance the group decision-making process. Its intention was to measure the extent to which this particular group perceived and valued every potential advantage and feature of the environment, and the degree to which barriers to using the technology prevented them from making optimum use of the environment.

To achieve those goals, the questionnaire enquired about respondents' usage patterns of the ICL, their perception of the value of the work environment, their perception of how their individual performance and that of their group improved when working in an environment like that of the ICL, and their perception of the technological and organizational barriers to using that environment. The questionnaire tackled different aspects of information communication, collaborative working, and usability as identified by technology acceptance models (Davis 1989, and Davis et al, 2000). Students were asked to rank features and tools of the ICL in terms of their

importance 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: primarily 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. The Likert scale questions in particular asked students to determine their level of agreement or disagreement with statements expressing the advantages and disadvantages of the ICL. While the phrasing of the statements (as specific advantages and disadvantages) is biased in favor of the environment, this particular phrasing of the statements was intentional to determine the extent to which students agreed with the relative advantages and disadvantages of interactive workspaces as identified by the literature. Closed-ended questions were also 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 2 shows a summary of the design and content of the survey.

*Table 2: 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. Of those surveyed, typical use of the ICL was between 20 to 30 hours in total, meeting between 2 and 3 hours every week.

Fig. 6 shows average responses to a survey question asking them to assess different aspects of information management in the ICL. As depicted, students agreed most with the ICL's ability to prevent information loss or misrepresentation and agreed least with its ability to facilitate information access and retrieval.

More than 90% of students found that information rarely got lost or misinterpreted during their meetings in the ICL. 80% of all students agreed that the ICL environment improved information communication within their group. 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 explanations as to why the majority of respondents did not find access and retrieval of information, in particular, easier in the ICL. Students might not have had the opportunity to explore the environment from this perspective: 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 (e.g., hard disks, CDs, memory cards) 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.

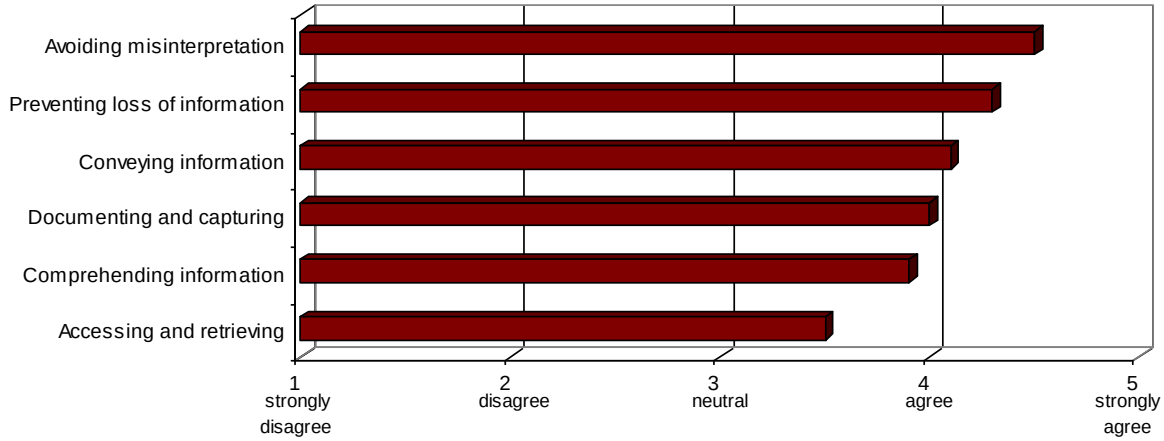


*Fig. 6: Students' perception of different aspects of information management in the ICL*

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. 7 and 8 summarize the results in terms of individual, and group performance respectively.

In terms of individual performance, as shown in Fig. 7, students found increased participation to be the most important advantage to using the ICL. Yet at the same time, they found the ease with which they were heard to be the least important advantage to using that environment, which raises concerns about the value of that increased participation if it does not result in increased attention. In terms of group performance, as shown in Fig. 8, students found the speed with which consensus was reached, and their productivity as a group to be the two most important advantages to using that environment.

Despite their overwhelming agreement with statements suggesting improvements in individual and group performance when working in the ICL, a small minority of students 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.

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 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 therefore working at a slower pace in response to those distractions.

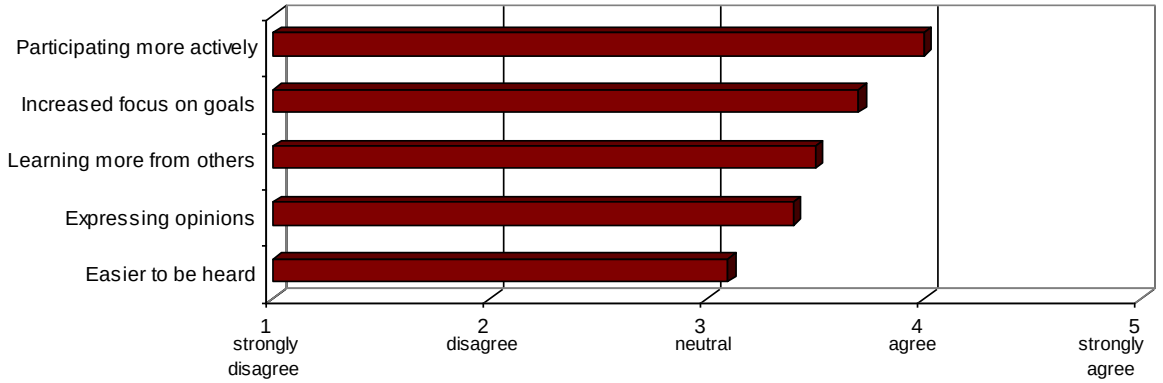


*Fig. 7: Students' perception of individual performance in the ICL*

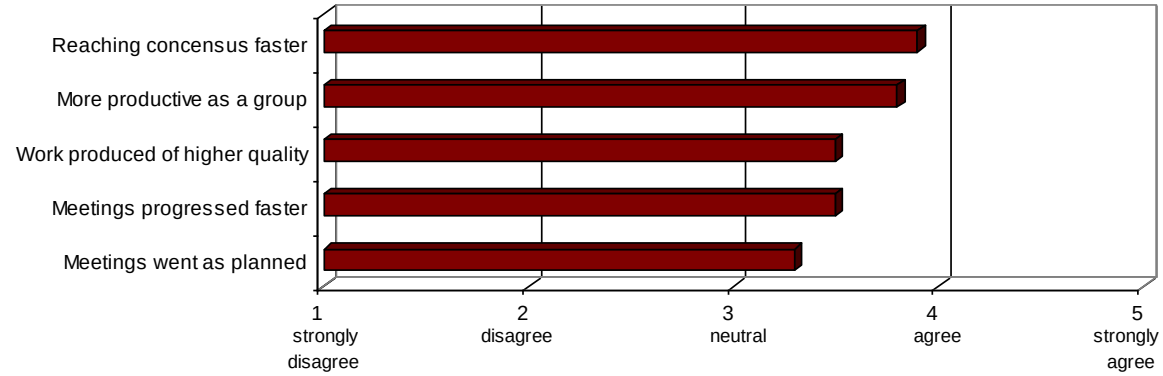


*Fig. 8: Students' perception of group performance in the ICL*

With regards to the ICL's technology acceptance, Fig. 9 shows that the largest barriers to using the ICL was students' uncertainty about how the ICL would be useful for their particular needs, and the learning curve associated with using the technology for the first time. 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.

Despite those results, it is important to note from Fig. 9 that students never considered any of the barriers listed in the questionnaire critical barriers that would prevent them from using the ICL environment effectively. Students' responses in general to that question remained positive. Students never agreed with any of the potential barriers listed in the questionnaire. They remained neutral at worst to most of the barriers listed, and disagreed with the rest of them. Those barriers did not seem to be an issue to this group of users. Nevertheless, they could be to other groups of users who might not be always completely up-to-date with current technology, or have the same technological skills students have. It is therefore important that responses are read with respect to the group of users that is being surveyed since different groups of users might behave and respond differently to the same set of circumstances and questions.

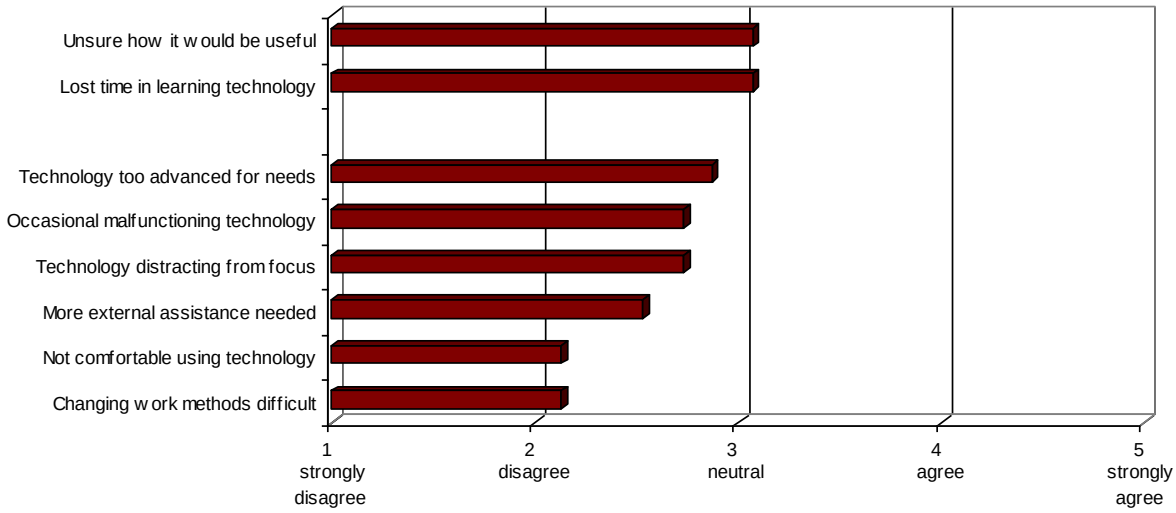


*Fig. 9: Students' perception of barriers to using the ICL*

The question asking students to rank the 5 input devices available in the ICL in terms of their usefulness produced surprising results. As depicted in Fig. 10, 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.

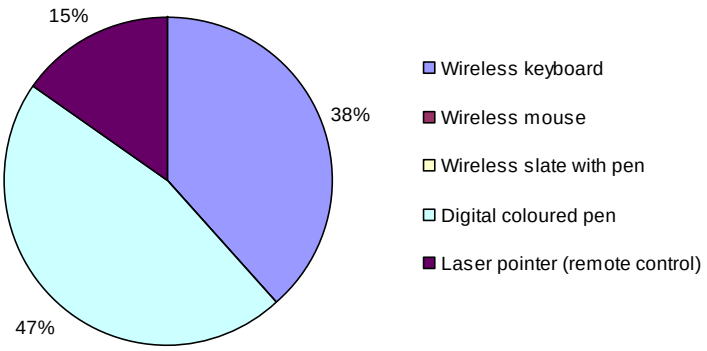


*Fig. 10: Most useful input devices in the ICL*

Fig. 11 represents students' opinions about design activities for which the ICL would be most useful. An overwhelming majority of students (72%) agreed that the ICL was most useful for investigating building and site 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 collectively.

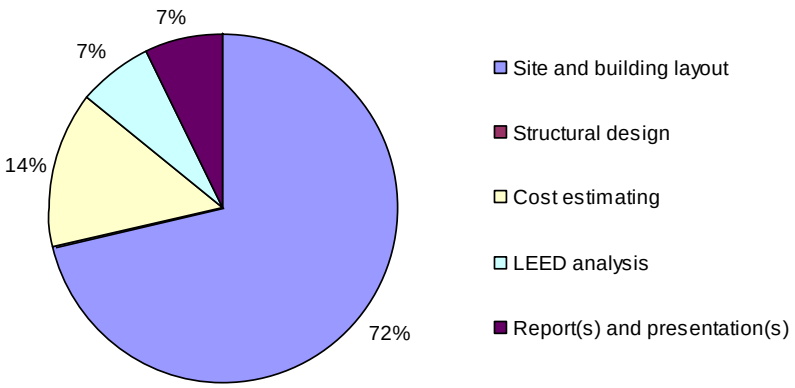


*Fig. 11: Design activity for which the ICL would be the most useful*

Quite surprisingly, results in Fig. 12 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, toward more accurate, and less biased results.

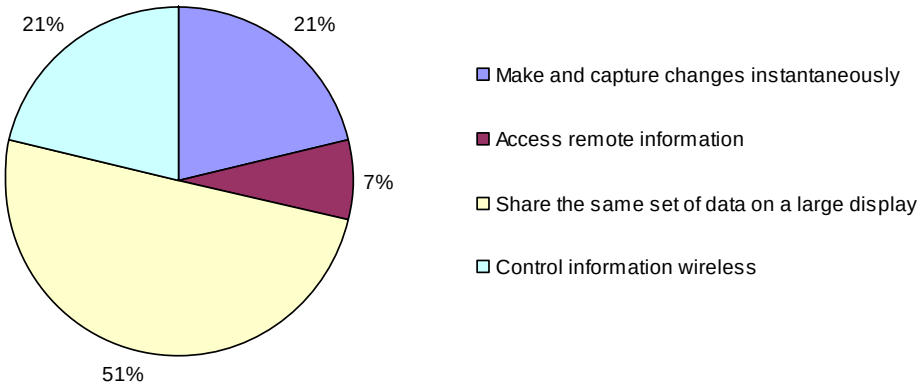


*Fig. 12: Most important feature of the ICL*

As shown in Fig. 13, 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, 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.

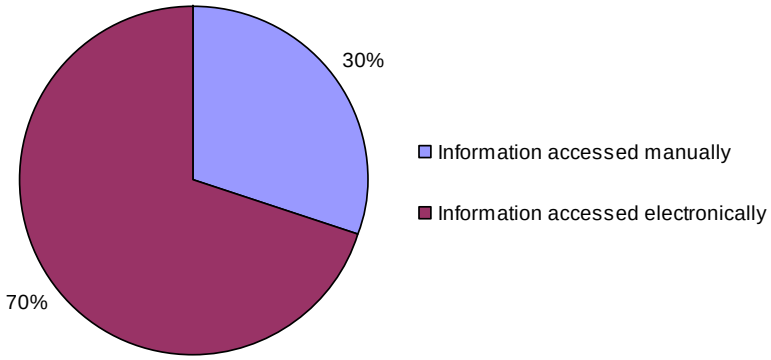


*Fig. 13: Percentage of information accessed manually versus electronically*

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 ICL2 because of its bigger size, and because of their ability to use ICL2 and ICL3 together as a single larger display.

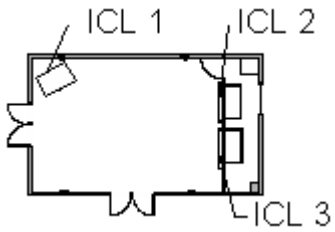


*Fig. 14: ICL boards identification*

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. 15, students found the ICL most useful for descriptive tasks, and least useful for predictive tasks. In fact, 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 and therefore require an appropriate setting, environment, and tools to support them.

It should be noted that unlike other studies such as Maldovan and Messner (2006), this study does not attempt to accurately measure or quantify the amount of time spent on every task type in an environment like that of the ICL. Instead, it simply enquires about students' perception of how useful the ICL was for every task type. While the study gives an estimate of that percentage value for every task type, it is important to note that those estimates might not be as accurate and conclusive as values derived from observational studies. Students were asked to provide very rough estimate of those values. Those estimates were based upon their personal limited perception of the whole experience, and not upon calculated, documented data derived from personal observation. Students were simply provided with short definitions for the categorization of decision-making tasks without the underlying theory. Therefore, it is essential that if this aspect of the study is explored further a more precise method should be employed.

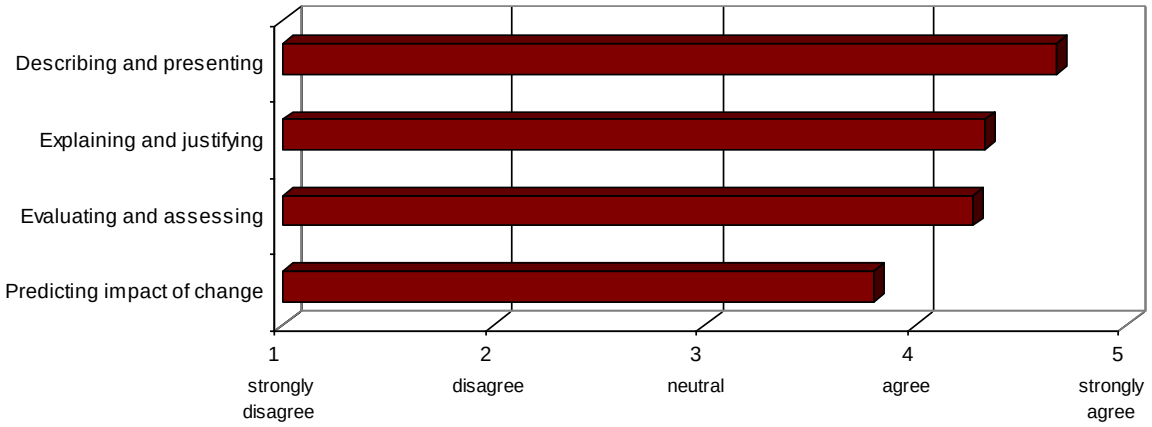


*Fig. 15: Usefulness of the ICL for different types of decision-making tasks*

The open ended optional question of the survey asked students to write down any additional comments they had about their experience of using the ICL. 8 out of 22 (36%) students answered this question. Below are excerpts of the most interesting comments received from students:

- "It was useful, yet at times frustrating…The ability to wire in with other computer is nice, and moving the furniture allows for a flexible space. I feel that these new rooms are early on in the adoption phase, and as technology is refined for these particular rooms, it will increase in efficiency.
- "It was a bit overwhelming for us to be placed into a room with all the technology at first, since we found ourselves playing with it for a while, but when it came time to get something done the distraction of the gadgets was past….My group started using it in the first couple of weeks and towards the end of the term we were getting the full use of it…"
- "...I found that there was more conflict in the ICL than in other rooms, as ideas tended not to be as well thought out or prepared. i.e. people would draw on the smart boards just for the sake of drawing on them..."

The feedback received from students for this last question has confirmed the results of the analysis of their earlier answers. Students believe that the technological infrastructure of the ICL needs to improve in order to facilitate users' control of the environment. They also feel that first-time users of the environment need to overcome its overwhelming and distracting nature when they first start using it, and need to go through a steep learning curve in order to make better use of it in the long run. They also believe that the ICL has a lot more to offer; which is why it is important that more advanced users find ways to enhance their use of the environment, in order to improve the quality and effectiveness of their activities.

## 4. LESSONS LEARNED

With respect to the whole environment for this particular user group, the ICL was found to be a healthy and comfortable environment that encouraged collaboration among members of the team. It was also found to be an environment that minimized distractions, supported group learning, and improved information communication. The ICL was less effective in improving work productivity, and decision-making. Therefore, there is a need to provide users with means and tools that would enable them to improve those two aspects. Participants might need to be briefed on the different decision-making techniques and meeting productivity improvement options available to them before they are allowed to use the ICL to ensure they work more productively and make more effective decisions once they start using the environment.

In terms of information management, the ICL has proven to be primarily effective in preventing loss of information, and information misinterpretation. It was found to be less effective in accessing, retrieving, and capturing information. To improve on those aspects of the environment, enhancements are required to overcome physical barriers to control, access, and capture of information (by replacing all wireless infrared keyboards and devices with radio-frequency identification devices for instance). Another suggestion would be to define and use a minimum of two working surfaces or platforms per group of users (each surface with its own input-output device(s)): one surface that would be used exclusively to access and retrieve information, and a second one which would be used to capture, document, and develop new information and ideas.

With respect to individual and group performance, the ICL was most effective in increasing participation, gathering support for interim decisions, and encouraging decision-making by consensus. It was found to be more prohibitive in terms of encouraging individual expression, and giving every member of the team the opportunity to voice their opinions, and listen to others. There was less agreement on the speed with which meetings progressed, and the extent to which meetings agendas were followed. Therefore, future research needs to focus on identifying and removing barriers to individual expression, and on investigating and addressing barriers slowing down meetings, and preventing users of those workspaces from following set agendas.

The ICL was found to be more useful for descriptive and explanative tasks than for predictive and evaluative ones. Users found the environment most useful in presenting available information to others in the team, and in improving communication and sharing of information among team members. They also found it facilitated explanations, and promoted greater understanding among members of the team. Nevertheless, they believed the environment less useful in generating and developing new ideas, in making interim decisions, and in drawing conclusions based on previous work. The environment was less effective in enabling users to evaluate and assess project goals, progress, and requirements and least useful in predicting the impact of changes on specific project decisions. Therefore, there is a need to encourage and enable users of the environment to focus on predictive and evaluative tasks because of how valuable those tasks are to effective collaborative decisions. Participants need to be briefed on the different types of tasks, meetings modes, and ICT usage contexts taking place in collaborative meetings, and be pushed to use the tools and techniques that will enable them to collaborate rather than coordinate, predict rather than review, and evaluate rather than describe or explain.

In terms of technology acceptance, the ICL's technology was found to be relatively easy to learn and operate. External assistance required was minimal. Despite its ease-of-use, there was a steep learning curve associated with using the technology; students lost time initially in order to learn how to take advantage of the ICL's technology. Understanding how best to use the technology in order to meet the groups' specific needs was found to be the most significant barrier to effective use of the environment. Participants were not always certain about how the available technology could improve their work. Therefore, more support is required to explain potential advantages of the technology to users of the workspace, and give examples of how the technology could be utilized in different scenarios and circumstances.

This survey has been used to investigate the usefulness of the Interactive Collaboration Laboratory for senior undergraduate civil engineering students using it for their senior team design project meetings. The survey investigates the advantages, limitations, and opportunities of that environment for this particular group of users, and for these particular types of meetings. While the survey provides meaningful results, it is important to remember that the environment is analyzed from their perspective, and is therefore based upon their subjective opinions. All advantages, disadvantages, limitations, and opportunities of the laboratory are presented, as perceived by those students. It is also important to remember that only 22 students were surveyed. A larger

number of students would have generated more accurate and comprehensive results. All students surveyed were novice users who had never used an interactive workspace before. Many of them had never studied the issues covered by the survey in depth. Therefore, it is important that results are read in that respect, since different users and usage scenarios might produce different results. The survey only investigates students' perceptions, opinions, and attitudes with regards to the general usefulness of the laboratory, and with regards to how the lab affects group meetings. Observational studies that rely on external, independent people to monitor actual meetings inside the laboratory should be able to assess, measure, and quantify those different variables more accurately. These studies would provide more meaningful and significant conclusions about the extent to which the use of the laboratory impacts the issues identified in the survey.

## 5. CONCLUSIONS AND FUTURE DIRECTIONS

This survey reflected the experiences of first-time users of an interactive workspace for design project meetings. The survey assessed different aspects of information communication, collaborative working, and individual and group performance when meeting in this environment, and investigated some of the technological and organizational barriers to effective use of this workspace. The survey also identified the design activities for which the interactive workspace would be most useful, and categorized different features of the workspace in terms of their importance, usefulness, and value to first-time users. It also compared between the amounts of information accessed electronically and manually in the workspace. The survey analyzed input devices in terms of their usefulness to those users, and analyzed trends in ICT tools' usage. The results of this survey were limited by its small sample size, the limited experience of its respondents, and its qualitative, rather than quantitative focus. They survey was administered to 22 respondents, all of whom had limited knowledge about the different issues investigated in the survey. All respondents surveyed were students who had used the ICL for less than 4 months at the time of the survey. The survey focused on getting students' opinions about the perceived benefits and limitations of using the ICL instead of quantifying those benefits and limitations and getting students to measure them in their meetings.

Despite their numerous perceived advantages, interactive workspaces, just like ICT tools, continue to be adopted and implemented slowly and cautiously among practitioners. This is due in part to ICT tools remaining a costly investment that small and medium sized construction companies are unable to justify. Furthermore, a comprehensive framework that identifies opportunities for effective use of those tools, and measures their specific impact on the effectiveness of group-decisions and related processes, does not yet fully exist.Efforts are 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 completing the development of a design studio aimed specifically at undergraduate students working on team design projects. On the industrial front, additional partnerships with practitioners are progressing through initial sessions within the ICL for design, planning and control of building and infrastructure project scenarios which lead to the establishment of on-site environments.

## 6. ACKNOWLEDGEMENTS

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