Assessing Support for Creativity: a User Evaluation of the Envisionment and Discovery Collaboratory (EDC)

ABSTRACT
Creativity is an important factor in collaborative activities such as design. Many researchers have developed design tools and environments to support the design process and creativity within the design process. However, with a few exceptions, the understanding and support of creativity has received little attention in the design community. Even in the exceptions, there has been little reported effort to perform evaluations of the design tools and environments in terms of their effectiveness at supporting creativity. In this paper we report a user evaluation of one of the few support tools with an explicit focus on supporting creativity in design activities – the Envisionment and Discovery Collaboratory (EDC). The results of this evaluation will lead to future developments of the EDC and recommendations for future creativity support tools and design environments.

Author Keywords

ACM Classification Keywords

INTRODUCTION
Well-known approaches within HCI such as Participatory Design (PD) and User Centered Design (UCD) epitomize the collaborative nature of design, bringing together stakeholders from diverse backgrounds to work together in both the analytical and creative practices of systems development [26]. Even in design processes that do not explicitly encourage user participation, an individual designer rarely works in isolation.

Within the CSCW community, many researchers [e.g. 1, 7, 10, 19, 24, 39] have developed design tools and environments to support the design process as a collaborative activity. Although there is a recognition of the need for theory in CSCW research [18], such tools and environments typically have been developed on the basis of practical knowledge and experience with little underlying theory. Our research aims to inform the development of design support tools and environments by increasing our theoretical understanding of both individual and group creativity in design.

With a few exceptions [e.g. 10, 37], little research has been conducted looking at creativity from the perspective of such design environments. Shneiderman [37] takes a theoretical perspective on the design of creativity support environments, basing his reasoning on the development of his Genex framework, which has evolved from previous Codex and Memex frameworks [6, 36]. However, the Genex framework is focused on ad hoc remote collaboration – an individual working on her own and distributing knowledge via resources such as the web – which does not capture the essence of collaborative face-to-face interaction in design. The Envisionment and Discovery Collaboratory (EDC) [10] is one of the few design environments that are focused on face-to-face social creativity and its support. Fischer [10] describes creativity as the product of a symmetry of ignorance, quoting Snow’s claim that ‘the clashing point of two subjects, two disciplines, two cultures ought to produce creative chaos’ [38]. Communication difficulties often occur between stakeholders but rather than this being an obstacle during design, Fischer [10] views it as an opportunity for creativity. By having different viewpoints, one can discover design alternatives and shared understanding.
Such a view of creativity, however, does not explain how and why such ‘creative chaos’ comes about.

While a few researchers have explicitly set out to support creativity in the development of their design environments [e.g. 10, 37], there are no published user evaluations of such tools and environments from the perspective of creativity. Hence, it is difficult to assess whether and how design tools and environments are actually facilitating creativity.

In this paper, we first seek to establish a deeper theoretical understanding of creativity in design which has been developed through our research [43-45]. We then introduce the EDC [10] and report the results of a user evaluation assessing the EDC’s support for creativity, leading to recommendations for the design of creativity support tools, including future developments of the EDC.

UNDERSTANDING CREATIVITY
Definitions of creativity have been developed and evolved over several decades. There have been three main concepts by which creativity has been defined: the creative process [e.g. 4, 20], the creative person [e.g. 16, 17] and the creative product [e.g. 2]. While the focus of definitions of creativity has evolved over time, from process to person to product, these are all essentially important components of creativity [23]. Each individual, or member of a group, has certain creative abilities (i.e. the creative person); she may explore and transform conceptual spaces, combining matrices of thought to generate new ideas (i.e. the creative process); and these ideas may consist in or lead to the development of a final product (i.e. the creative product). In the example we consider in this paper, the products of the creative process are the design ideas generated to solve the design problem at hand. In assessing the creativity of an idea, we consider two criteria: novelty and appropriateness. A design idea is deemed creative if it is new or unusual to the mind in which it arose (novelty) and conforms to the requirements of the design problem (appropriateness) [43, 45].

Fischer [12] refers to creativity as knowledge creation, integration and dissemination, with the use of boundary objects. Boundary objects [5] are externalizations of ideas that are used to communicate and facilitate shared understanding across spatial, temporal, conceptual and technological gaps. They allow stakeholders to move away from vague mental conceptions of an idea to more concrete representations; to interact with, react to, negotiate round and build upon ideas; and to frame and understand the problem at hand.

Drawing on our previous work investigating the production and use of shared external representations and understandings in the social creative process of PD [26, 27], we have developed a theory [45] that explains the creative potential of collaborating groups in creative activities such as design. The members of design teams are able to interact with each other and have the ability to externalize their matrices of thought to other members of the group (i.e. through boundary objects), effectively forming an external shared representation of their matrices of thought [26, 27]. These externalizations can support the creation of shared understandings and the development and evolution of knowledge and understandings through ‘talk back’ situations [13]. Stakeholders in design teams with different domains of knowledge may collaborate on a design problem. Social creativity emerges as a result of the participants’ knowledge construction, through the use of boundary objects, leading to new and extended boundary objects, increasing shared knowledge and understandings.

THE PROBLEM WITH CREATIVITY IN COLLABORATIVE DESIGN
Gennari and Reddy [14] describe the design process as ‘human activity, involving communication and creative thought among a group of participants’. A fundamental question about activities such as collaborative design that involve a social component is: what effect does the social nature of this activity have on creativity?

In 1958, Taylor et al [40] conducted a study comparing real groups (i.e. face-to-face interacting groups) with nominal groups (i.e. individuals working on their own and then collating their outputs to form a cumulative output), to test Osborn’s claim that ‘the average person can think up twice as many ideas when working within a group than when working alone’ [29]. Taylor et al found that nominal groups produced nearly twice as many non-replicated ideas as real groups – refuting Osborn’s claim. Since the Taylor et al study, over 50 years of empirical studies have shown nominal groups to outperform real groups [25]. The implication of this body of research is that collaborating groups, such as design teams, are not being as creative as they could be.

The three major explanations that have been explored by the creativity community as to why nominal groups outperform real groups are the social influences of procedural mechanisms (i.e. production blocking), social psychological mechanisms (i.e. evaluation apprehension) and economic mechanisms (i.e. free riding).

Production Blocking
Production blocking has been argued [9, 22] to be the most important cause of nominal groups outperforming real groups. Production blocking is common when ideas are expressed verbally within a group. Verbally expressing ideas is a form of asynchronous interaction. The problem with asynchronous forms of interaction is that group members are prohibited from simultaneously expressing their ideas. They may subsequently forget their ideas or suppress them because they may feel their ideas are less relevant as time passes. Another problem is that they may rehearse their ideas internally, preventing them from concentrating on what other members say. Finally, if group members are prevented from expressing their ideas as they occur, they may be discouraged from producing further
ideas. To mitigate the effects of production blocking, researchers [8, 32] have moved towards using synchronous interaction techniques for expressing ideas. Prante et al [33] describes the use of single display groupware (SDG) and synchronous groupware systems (SGS) to prevent production blocking in real time collaboration.

Evaluation Apprehension
Evaluation apprehension occurs when group members fear criticism from others within the group. This can prevent group members from expressing ideas. The negative effect of evaluation apprehension reduces the quantity of ideas produced in groups. To overcome the negative effects of evaluation apprehension, it has been suggested by some researchers [e.g. 32] that anonymous means of expressing ideas remove an individual’s identification with an idea and therefore help encourage people to express their ideas without fear of criticism. Some technologies described in the CSCW community [e.g. 8, 33, 41] allow for anonymizing individual input, thereby reducing evaluation apprehension.

Free Riding
Free riding, otherwise known as social loafing, is the result of group members’ becoming lazy, relying on other members in the group and not contributing as many ideas as they could. When working in a group, group members may assume the group’s output to be assessed collectively, whereas when working alone one has to take responsibility for one’s own performance [9]. Therefore, assessing members within a group on their individual performance rather than on the group’s performance reduces the effect of free-riding. Paulus [30] also refers to social stimulation as a way to reduce the impact of free-riding – encouraging a high motivation level in groups by increasing accountability for individual performance. Various studies [e.g. 31] have shown that providing groups with a comparison standard increases their performance and providing explicit feedback about individual performance also improves the performance of group members.

The Need to Control Social Influences
Drawing on our theory of collaboration in creative tasks, our previous experimental work has demonstrated that controlling the social influences of production blocking, evaluation apprehension and free riding has a strong positive effect on the generation of creative ideas in a real group setting [44]. Hence, we argue that creativity support tools need to focus on facilitating creativity from the interaction and collaboration of stakeholders by supporting knowledge creation, integration and dissemination; and by reducing the social influences of production blocking, evaluation apprehension and free riding which hinder creativity in groups such as design teams.

THE ENVISIONMENT AND DISCOVERY COLLABORATORY (EDC)
The EDC [3] is a computerized tool for supporting creativity. The main goal of the EDC is to ‘support social creativity by creating shared understanding among various stakeholders, contextualizing information to the task at hand, and creating objects-to-think-with in collaborative design activities’ [10]. While the EDC in concept can be applied to many collaborative activities, its test bed domains have been urban planning and decision making. The current implementation of EDC comprises a projected image on a table which can be manipulated via physical objects using an embedded grid structure within the table and an ultrasonic sketching tool, allowing boundary objects to be created and evolve, facilitating interaction and communication between participants.

We report here an evaluation of the EDC. The aim of this evaluation was to assess the EDC for its support of creativity, leading to a deeper understanding of group creativity and recommendations for the further development of the EDC and future creativity support tools.

EVALUATION OVERVIEW
We evaluated the EDC as a creativity support tool, assessing different attributes related to the design of the EDC and the support of creativity. The evaluation was conducted through the use of video observations and a post-questionnaire capturing quantitative and qualitative data. We examined:

1. Aims and objectives of the EDC [3].
2. Interaction and communication amongst participants through the use of boundary objects [11, 13].
3. The support and facilitation of idea generation [45].
4. The control of inhibiting social influences on creativity [9, 45].
5. Group composition around the interaction space [44].
6. Miscellaneous: group feelings, opinions of the group and the groups use of the EDC.

METHOD
The evaluation had a between participants design. The evaluation involved groups of four participants, collaborating together to decide on the future development of land-use and the development of new bus routes, including bus stops, for the Gunbarrel area of Boulder, Colorado. Interaction with the EDC and amongst the participants was captured for post-analysis through the use of two digital video cameras and Camtasia screen capture software. A questionnaire was also given to the participants after completing a trial, evaluating the EDC on various
attributes related to the design of the EDC and the support of creativity.

**Participants**
Twenty-eight participants took part in the evaluation, forming seven groups of four. The participants varied in age from 20 to 57, with a mean of 33.25 years. All participants were from the Boulder area of Colorado, consisting of undergraduate students, postgraduate students, university staff and public sector workers. The participants were recruited from mailing lists, posters and word of mouth.

**Equipment**

![Figure 1. The Envisionment and Discovery Collaboratory.](image)

The set up of the EDC can be seen in Figure 1. The EDC is a square table, with a projected graphical image on the surface of the table, an embedded grid structure for detecting physical objects using RFID tags in the table, and an eBeam ultrasonic sketching tool. The input from the physical objects and the eBeam device are fed back to a standard desktop PC, which outputs the resultant graphical image via a projector on to the table surface.

![Figure 2. The projected graphical image of the EDC.](image)

The projected graphical image (see Figure 2) displayed a map, a tool menu and a sketch menu, which can be manipulated via the physical objects and the eBeam sketch tool. The tool menu, which was controlled via the Admin block (see below) allowed the user to select from three options: view a satellite image of the Gunbarrel area of Boulder (i.e. Aerial option); view a road map of the area (i.e. Map option); and a Hide option which toggled through the options of land use colouring being shown or hidden. The sketch menu, which was controlled via the ultrasonic pen, allowed the users to sketch on the map. When a new sketch was created, the user had the option to: minimise the sketch; bring the sketch to the top (if multiple sketches were present); and close the sketch. There was also a colour palette projected on the table which allowed the users to choose a line colour and a fill colour using the ultrasonic pen. In addition, there was an erase option, which could be selected using the ultrasonic pen, which then allowed the users to select lines and filled shapes with the ultrasonic pen to erase them.

The embedded grid structure in the table was used to detect the position of eight physical objects. Each object had a different function as noted below:

1. Admin – This was a selection block to be used on the tool menu. This block was used to change between the aerial, map and hide options.
2. Single-family residential (Yellow) – This block placed a yellow square in the cell in which it was positioned on the map, indicating low-density housing, e.g. detached housing.
3. Multi-family residential (Orange) – This block placed an orange square in the cell in which it was positioned on the map, indicating high-density housing, e.g. apartments.
4. Agricultural (Brown) – This block placed a brown square in the cell in which it was positioned on the map, indicating farm land.
5. Light industrial (Blue) – This block placed a blue square in the cell in which it was positioned on the map, indicating warehouses and small factories.

6. Commercial (Red) – This block placed a red square in the cell in which it was positioned on the map, indicating shops and offices.

7. Open Space/Parks (Green) – This block placed a green square in the cell in which it was positioned on the map, indicating open land suitable for walking, playing and relaxing.

8. Remove – This block removed a land-use type (blocks 2-7) and reset it to neutral, by placing the block on the cell containing a land-use type you wished to remove.

During the evaluation, audiovisual data was captured by two mini-DV cameras, one camera capturing a view looking down on the EDC, observing the users' interactions with the EDC; and the other camera capturing a wide view of the EDC and the participants, capturing data which may have been lost by the other camera. In addition to the mini-DV cameras, Camtasia software captured the screen images on the PC running the EDC.

A notebook computer was also used to play a set of audio instructions to the participants before the evaluation started.

Procedure
Participants were run in randomly assigned groups of four. Upon each participant signing a consent form to participate in the evaluation, the participants were asked to take a seat around the EDC while the pre-recorded instructions were played. (Participants could be seated or stand during the evaluation task.) Pre-recorded instructions were used to minimise the evaluator’s contact with the participants. The pre-recordings gave an overview of the evaluation; an introduction to the EDC and its functionality; a practice task; a description of the evaluation task. After each audio file the evaluator asked the participants if they had any questions and tried to answer them to the best of his ability. It was emphasised to the participants that we were evaluating the EDC and not the users. Creativity was never mentioned, as Amabile [2] argues that participants’ performance changes if they are aware that they are being assessed on creativity.

The functionality of the EDC was described to the participants via an audio recording. While the audio recording was playing, the evaluator demonstrated the described functionality in sync with the recording, so the participants were provided with an audio and visual demonstration of the available functionality. A list of the available functionality as described in the audio recording was available on the wall next to the EDC and could be referred to by the participants at any time during the evaluation.

In order that the participants were aware of the available functionality of the EDC, all participants engaged in a practice session. The evaluator read aloud the tasks one at a time from a script. When the participants completed the current task, the evaluator moved on to the next task, until all practice tasks were complete. The evaluator did not have to intervene during this process. If one person was confused about a particular task, the other participants in the group helped to clarify it.

After the participants had completed the practice tasks, the evaluator randomly handed each participant a slip of paper which had a role play description, which they were asked to read in private. The EDC is a domain-oriented design environment, intended for real users to collaborate together on real world problems. We did not have access to ‘real’ users to collaborate on a transportation and development task, and surrogate users lack motivation to engage in such a task as it is not a personally meaningful activity [13]. Therefore role-play scripts were used to inform semi-authentic users. The use of these role play scripts increases the user’s motivation as it makes the task more meaningful and it also promoted the ‘symmetry of ignorance’ [11].

Before the evaluation task was played to the participants, the evaluator loaded the EDC image file as a starting point for the evaluation. The image file contained a pre-defined map with land-use types marked up, and sketches of an existing bus route and bus stops for the Gunbarrel area of Boulder displayed.

Once all participants had read their role play scripts, the evaluator played the evaluation task description:

You are a group consisting of 2 residents, 1 developer and 1 city planner. You have come together to discuss the future development of the Gunbarrel area in Boulder.

Resident (R1) – You live in the south-west area of Gunbarrel. One of the reasons for you moving to this area was its location near the countryside. However, the area in which you live is a new residential development. As yet the local bus route does not serve your area, which makes getting into Boulder and to your place of work in the north-west difficult. You would like to see the bus route extended to your area to meet your transportation needs.

Resident (R2) – You live in the north-east area of Gunbarrel. You enjoy taking your dog for a daily walk in the local farm land. However, for a long time now you have been unhappy with the position of the bus-stop outside your house. This causes your dog to bark when people are waiting for the bus and are getting off the bus, causing disruption to yourself and your neighbours. You would like to see the bus stop moved for a more peaceful life.
Developer – Due to an increasing demand for residential, industrial and commercial property, you are looking to buy as much land as possible to meet the growing demands – any open space and agricultural land has the potential for development. You wish these new developments to tie into the existing infrastructure and have good transportation links into Boulder.

City Planner – You wish to have developments to increase the economy in Boulder. You realise the current bus route is old and inadequate, but areas which are not served by the current bus route do not have a high enough demand, therefore costs cannot be justified. You wish the bus route or routes to serve the most highly populated areas for maximum profit. You also wish to position bus stops along the bus route or routes to best serve the Gunbarrel community.

The tasks for the group are as follows:
1) Discuss and come up with ideas for the future development for the Gunbarrel area of Boulder – both land-type and transportation. You have an upper limit of 30 minutes for this task, unless the group finishes sooner and are happy.

2) From the ideas generated in task 1, discuss between the group members and come up with a final solution for the future development of Boulder. You have an upper limit of 10 minutes for this task, unless the group finishes sooner and are happy.

Please engage in your role playing scripts as much as possible, using the information provided and your own personal opinions and experience.

A description of the evaluation task and roles as described in the audio recording was available on the wall next to the EDC and could be referred to by the participants at any time during the evaluation.

Once all questions had been dealt with by the evaluator, the cameras were set to record and the evaluation task began. The evaluator sat at a distance from the EDC, to remind the participants after 30 minutes that they had 10 minutes left and should work towards a final solution if they hadn’t already begun to do so. After 40 minutes the evaluator informed the participants that their time was up and asked them to draw to a conclusion. To conclude, the participants were asked to complete a post-questionnaire about the EDC.

FINDINGS

The findings which we report in this paper are drawn from the post-evaluation questionnaire. The questionnaire used 5-point Likert scales to gather quantitative data on the users’ opinions of attributes related to the design of the EDC and its support for creativity. The results are presented below according to the issues we examined:

1. Aims and objectives of the EDC [3].
2. Interaction and communication amongst participants through the use of boundary objects [11, 13].
3. The support and facilitation of idea generation [45].
4. The control of inhibiting social influences on creativity [9, 45].
5. Group composition around the interaction space [44].
6. Miscellaneous: group feelings, opinions of the group and the groups use of the EDC.

Mean responses are given out of 5 with the standard deviation in parentheses. Each quantitative response was followed by a space for users to reflect upon their answers, giving qualitative feedback to complement the quantitative data.

Achieving the objectives of the EDC

The development of the EDC was based on three main objectives [3]:

1. To bring a variety of aspects (social, cultural, physical, virtual) together to support the creation of shared understandings.
2. To allow users to develop as they learned new information as the task progressed.
3. To evolve and meet the needs of the users as both the user and the task progressed.

The users rated agreement that objectives 1 and 2 had been achieved relatively highly, scoring 3.85 (0.72) and 4.11 (0.50) respectively. Participants commented on how the EDC allowed people’s different perspectives to be voiced, which in turn facilitated a shared understanding. This was a primary goal of the EDC, allowing the ‘symmetry of ignorance’ to occur [11] – discovering design alternatives through talk back and breakdowns [11]. Participants noted that this shared understanding increased throughout the task, allowing them to evolve their ideas and increase their productivity. However, participants were more neutral about objective 3, with a mean score of 3.26 (0.94). The EDC was meant to act as an open system [10], but within the scope of the domain of urban planning, participants commented on the EDC being ‘concrete rather than abstract’; ‘the EDC is rigid in its functionality; no room for altering methods to fit learning needs’; and ‘it felt like we really had to work around some of the aspects to get what we wanted’. Despite this, participants did acknowledge that they had enough functionality for the task at hand.

Fischer [10] refers to empowering users to become engaged in expressing personally meaningful ideas, rather than settling for the lowest common denominator. Users of the EDC strongly agreed that the EDC motivated them to
become engaged in the task and become an active contributor throughout the task, scoring 4.00 (1.02) and 4.07 (0.94) respectively. This is a very important feature with respect to creativity. Amabile [2] argues the importance of task motivation in creative activities, especially implicit task motivation as experienced here, when participants are motivated to engage and contribute for themselves, their knowledge and enjoyment, rather than for financial reward. It was noted by participants that they felt the technology encouraged them to become motivated in the task. This motivation induced an active contribution, although participants were primarily involved in their own agendas rather than those of others.

The EDC was also designed to allow the users to feel in control of it. However, users had a neutral opinion about this, 3.32 (1.02). One participant referred to ‘control being passed around with the pen’. The EDC had only one ultrasonic pen to act as an input device for the sketching tool. Sketching was the method preferred by the participants, so whoever held the ultrasonic pen also controlled the EDC. The pen was passed around amongst participants with no one person dominating it, which gave the participants a shared control over the EDC. However, one participant noted ‘the limitations of the EDC in some ways controlled what we could do, but for the most part I felt I was able to get my point across using what was available’. The limitation of having only one ultrasonic pen could have been more of a problem if participants wanted to perform tasks in parallel or if the design team consisted of more stakeholders.

**Interaction and communication amongst participants through the use of boundary objects**

One of the main features of the EDC was to allow the creation, integration and dissemination of knowledge through the use of boundary objects. There was strong participant agreement that this had been achieved, scoring 4.29 (0.66). Participants commented on the ability to make rapid changes without committing to them and to collaborate around these ideas (i.e. boundary objects). Participants were confident that anyone using the EDC could express their ideas to other, allowing ideas to be formed or integrated into others and disseminated to other participants quickly. The primary use of this was through the sketch tool, which allowed lines and shapes to be drawn rapidly, and manipulated and erased as they saw fit. Participants were able to move away from vague mental conceptions of an idea to more concrete representations in the form of sketches. They could then use these sketches as the basis for further collaboration. This suggests that the EDC acts as an effective medium for socially constructing and sharing information. As one participant commented, ‘there was a lot of room for collaboration’. However, as one participant also commented, ‘so does paper’.

**The support and facilitation of idea generation**

Participants also considered the EDC to be a useful tool supporting the process of idea generation, allowing new ideas to be developed, 4.00 (0.67), and existing ideas to evolve, 4.04 (0.76). In addition, participants were also happy with the presentation of ideas, 4.04 (0.74), allowing ideas to be combined, 4.04 (0.68), and improved upon, 3.96 (0.71). The sketching function was considered crucial by all participants, whether for the generation of new ideas or the combination and improvement of existing ideas, by allowing external representations to be provided. These sketches acted as boundary objects [5], where ideas were externalized to communicate and facilitate a shared understanding. Schön [34, 35] argues the importance of this where practitioners have a conversation with materials of a design situation, such as sketches, gradually building an understanding of the design problem and its solution. This conversation would not have been possible without the sketching tool. However, many participants did suggest the need for an undo/redo function, as it could be hard to edit the existing material.

Positive agreement about the way ideas were presented was also expressed, 3.89 (0.83). Participants found that the sketch layers allowed for an implicit organization of ideas, although the user had no control over this organization. This in turn led to moderate agreement that the EDC allowed ideas to be evaluated effectively, 3.50 (0.92). Ideas could be visually expressed and then evaluated by the group. It was suggested that presentation of multiple representations would have helped in the evaluation process, allowing comparisons to be made. It is an important feature of the EDC to support the organization and evaluation of ideas as the creative process is an iterative one, developing through phases of problem understanding and framing, idea generation and idea evaluation [2, 29, 37, 42].

**The control of inhibiting social influences on creativity**

Participants were also asked a number of questions to assess the effects of social influences (production blocking, evaluation apprehension and free riding) during the task. There was only moderate agreement, 3.43 (0.96), that the participants were able to contribute an idea whenever they had one without obstruction (i.e. the effect of production blocking). The EDC had only one ultrasonic sketching tool and there was only one physical object that could be used for each function. In addition, there was only one interaction space (i.e. the EDC table). This introduced a form of technological production blocking. If a participant had an idea she wanted to express using the EDC, she was constrained by the available features of the EDC and whether other participants were currently expressing ideas. We recommend that multiple pens are used to facilitate multiple user sketching and redundant blocks are provided to give multiple users access to the same functionality, thereby reducing the impact of technological production
Participants believed, 3.79 (1.03), that they were able to contribute ideas without fear of criticism; that is, there was little apparent evaluation apprehension. This was a somewhat surprising finding as the EDC comprises a public interaction space, allowing all the other group members to see the ideas generated. Follow-up analysis of the qualitative feedback data suggested that this was because of the positive, supportive environment in which the participants were working. Participants mentioned that the ability for them to contribute ideas without fear of criticism was a result of the people, not the EDC: ‘only because this was a friendly group, the EDC was not a factor here’.

There was quite low agreement by participants that everyone in the group contributed equally, 3.25 (1.00). This suggests a perception of free-riding. In contrast, all participants considered themselves to be active contributors. The participants did not expand upon why they thought not everyone contributed equally. Participants commented that they were concerned with their personal agendas and therefore considered themselves actively to be contributing towards the task at hand when the discussion affected them. This may have left other group members with the opinion that they did not contribute as much as they actually did. To understand this effect more, further analysis is required of the video data.

**Group composition around the interaction space**

An aspect of the EDC which was of particular interest was the support of individual, sub-group and group creativity, extending our work on the effect of group composition on creativity in design [44]. The EDC comprised a public interaction space (i.e. the EDC table) and participants gave a high rating to the support the EDC provided for working as a group, 4.39 (0.57). However, the support provided by the EDC for sub-groups and individual work was poor, 2.56 (1.00) and 2.68 (1.12) respectively. The low assessment of support for sub-group and individual work may be explained by the EDC’s provision of only a public interaction space, whereas social and private interaction spaces are more supportive of sub-group and individual work [21, 28]. The users’ assessment of the support for working individually was only slightly higher than that of the support for sub-group work. Follow-up analysis of the qualitative feedback data revealed that participants believed the EDC provoked individual insight, which was a goal of the EDC through the externalization of boundary objects. However, the support for working on these externalized insights in private was lacking. Participants also commented that they worked as a group, but sub-conversations did occur. The public interaction space supported the group work, but could not accommodate the sub-group collaboration. Therefore to meet the demands of individual and sub-group work, the EDC needs to provide technologies to support these various group compositions.

**CONCLUSIONS AND FUTURE WORK**

In this paper we reported a unique evaluation of a creativity support tool, the Envisionment and Discovery Collaboratory [3]. The EDC was evaluated in terms of attributes related to the design of the EDC and the support of creativity [43, 45]. Recent developments of the EDC have integrated sketch functionality via eBeam, meeting the user need for handwritten annotations and hand-drawn graphics. Future work in this area is moving from a single to multiple ultrasonic pens, reducing the effect of technological production blocking. In addition, soundscape have been introduced into the EDC, integrating technologies from pervasive computing and tangible interfaces [15]. The aim is to integrate different dimensions of creativity and support the social creative process of expression, interpretation and evaluation of information over a sustained period of time, through the use of multiple interaction spaces and social practices. These future developments are moving towards meeting the users’ needs, allowing for the better support of creativity in design.
The findings of the evaluation show the EDC to be an effective creativity support tool, empowering users in personally meaningful tasks to engage as active contributors, externalizing ideas and thereby allowing knowledge to be created, integrated and disseminated [12]. The EDC allowed users to interact and communicate with boundary objects [5], supporting the generation of new ideas through the combination and improvement of existing ideas. The EDC allowed effective presentation of ideas, which was useful to the users in generating new ideas and in evaluating these generated ideas.

However, the EDC does have room for improvement. Production blocking [9] was introduced via the EDC technologies. Making multiple sketching tools available to the users and having multiple objects for the same function would remove this asynchronous interaction problem. In addition, augmenting the public interaction space provided by the EDC using technologies such as Tablet PCs and PDAs, as suggested by Streitz et al [39], to provide social and private interaction spaces [21, 28] should better support individual and sub-group creativity. This should also have a positive impact on group creativity by reducing evaluation apprehension, allowing individuals to develop ideas before expressing them to the group [26].

We are currently pursuing this approach with the development of our creativity support tool PSPD (Public Social Private Design), a design environment for supporting individual, sub-group and group creativity. By providing multiple interaction spaces using mobile and pervasive technologies [21, 28], we can provide support for different types of creativity. In the PSPD, a tabletop display will provide a public interaction space (for the group); Tablet PCs will provide social interaction spaces (for sub-groups); and PDAs will provide private interaction spaces (for individuals).

In our ongoing work we are analyzing the video data collected from the EDC evaluation. This data is being analysed to complement and extend the findings reported in this paper. This analysis will provide further insight for future improvements to the EDC and other creativity support tools. In addition, we are extending this study with an experiment observing the effects on creativity with and without computerized support tools such as the EDC.

With answers to such research questions, we can look towards supporting social creativity, improving the practice of design and the development of design environments, ultimately leading to more usable and useful systems and applications.

ACKNOWLEDGMENTS

We would like to thank the LifeLong Learning and Design Centre at the University of Colorado, Boulder and the HCI Group at the University of Bath, UK.

REFERENCES

6. Bush, V. As we may think, (1945)
35. Schön, D.A. Designing as reflective conversation with the materials of a design situation. *Knowledge-Based Systems Journal, Special Issue on AI in Design, 5*, 1 (1992), 3-14
42. Wallas, G. *The Art of Thought*. Harcourt, Brace & World, New York, 1926
Contribution and Benefits statement:

User evaluation of a design tool/creativity support tool – the Envisionment and Discovery Collaboratory (EDC). The results provide recommendations for the future development of design tools and creativity support tools.