

Exploring the conceptual space of LEGO: Teaching and learning the psychology of creativity

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This paper reports on the use of the construction toy LEGO as an effective learning resource for undergraduate classes in the psychology of creativity. Students first attended a short series of lectures on aspects of creativity, including learner characteristics such as motivation and metacognition, and theoretical approaches to problem-finding and problem-solving including the Genevieve model and the metaphor of learning as navigation in a multidimensional conceptual space. This was followed by three sessions in which students explored the conceptual space of LEGO under each of three conditions: freeplay in session 1, constraints on process in session 2 (rules for assembly), and constraints on product in session 3 (set goals). Throughout this time, students were required to keep a 'metacognitive diary' of their experiences, and to reflect on their own learning processes within and across sessions. Evaluation was carried out by means of a post-activity questionnaire. The paper reports on the kinds of structures produced under each set of constraints, patterns of student learning experiences, motivational changes, and student evaluations of the activity as a whole. It is suggested that, used in this way, LEGO provides a simple, highly enjoyable, yet effective medium for teaching, learning and research in the psychology of creativity.

INTRODUCTION

Creativity as a learning process

Models of the creative process typically identify three distinct yet interacting forms of activity involved in creating a novel product (for example, Getzels and Csikszentmihalyi, 1976; Finke, Ward and Smith, 1992; Runco, 1994): (i) a problem-finding phase, in which initial ideas or problems are identified and formulated; (ii) a problem-solving phase, in which possible solutions are explored and elaborated; and (iii) a verification phase, in which the appropriateness of the product is evaluated according to a variety of pragmatic and/or aesthetic criteria. While there is a general progression from problem-finding to problem-solving to verification as creative activity proceeds, the process itself is an iterative one involving movement back and forth between one phase and another. A useful and influential heuristic model of this type from the cognitive literature is that of the Genevieve model (Finke *et al.*, 1992; Ward *et al.*, 1999). The Genevieve model conceives of creativity as a generative learning process involving the alternate construction and exploration of initial ideas or concepts termed *pre-inventive structures*, whose functional specificity and further refinement are determined at a later date by the constraints or goals imposed by a particular task. In this way, a composer might generate a musical motif, for example, which is later developed and explored within the context of a particular composition, or an author may draw upon novel combinations of words, and/or the insights such combinations afford, in evolving a written text.

The Genevieve model highlights how the imposition of task constraints on a final product during the generative or exploratory phases affects the creative

learning process. However, creative activity is also constrained by the wider set of cultural practices in which it is embedded (Csikszentmihalyi, 1999; Lubart, 1999). The composer who generates a musical motif, or the author who generates a constellation of words, does so with reference to a wider set of social conventions, values and beliefs that determine the meaning and significance of what is created. Boden (1999; 2000) refers to such culturally-given styles of acting and thinking as *structured conceptual spaces* and in ways that echo the Genevieve model, identifies three types of creative activity involved in their development and exploration: (i) combinational activity, in which familiar elements within the space are combined in novel ways; (ii) exploratory activity, in which possibilities inherent in the structured conceptual space are explored; and (iii) transformational activity, in which the space and its possibilities are transformed through changing one of its basic dimensions or rules. An historical example of the last would be the way that possibilities for composition in western classical music were radically altered by Schoenberg's use of the chromatic scale in place of the diatonic (Boden, 1999; 2000).

Aside from the wider sociocultural context and the associated acquisition of domain-specific knowledge and skills (Pollicastro and Gardner, 1999), other variables known to play an important role in creative learning are motivation and metacognition. In general, research shows high levels of creativity to be associated with high levels of intrinsic motivation, that are typically undermined by the provision or anticipation of extrinsic reward (Amabile, 1983; 1996; Hennessey, 1989; 1995). However, more recent conceptualizations of the intrinsic-extrinsic relationship in terms of motivational synergy (Collins and Amabile,

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1999) and self-determination theory (Ryan and Deci, 2000) suggest that under certain conditions, or at certain times in the creative process, optimal performance may occur when intrinsic and extrinsic motivation work constructively together in the same individual. Additionally, metacognitive skills have been shown to enhance creativity via conscious strategy choice and the intentional monitoring and evaluation of on-line behaviour (Jausovec, 1994). This includes the monitoring and control of motivation itself, as people can learn to consciously offset the negative effects of reward (Hennessey, Amabile and Martinage, 1989). As Sternberg (2001) has recently argued, much of creativity relies fundamentally upon a *decision* to be creative.

In summarizing the above, figure 1 provides a conceptual framework for the teaching-learning activity reported in this paper, based upon the central metaphor of learning as navigation through a multidimensional conceptual space.

LEGO as a conceptual space for investigating the creative process

The construction toy LEGO is an appealing learning resource for teaching the psychology of creativity in that it provides students with a simple, concrete example (or analogue) of a well-organised conceptual space (identifiable components, ‘rules’ for assembly and so forth) requiring only minimal domain-specific knowledge for its exploration. LEGO has massively expanded its basic range of bricks and other component pieces over the years, introducing many preformed items such as hinges, windows, wheels and so on, and an enormous variety of other model-specific components. As a consequence, several structures that would once have required creative problem-solving to construct arguably now no longer do so. By way of contrast, this paper outlines and evaluates a series of activities for undergraduate students that explores the pedagogical potential of

LEGO when the range of components is limited to a few basic building bricks and the rules for assembly are constrained. The project as a whole was conceived as action research aimed at investigating how students explored this particular conceptual space: what kinds of activity they engaged in, what kinds of structures they built, how these were affected by the imposition of task constraints, and what feelings and cognitions motivated and guided their behaviour, with a view to developing and refining the use of LEGO as an educational resource and research tool.

METHOD

Participants

The activities reported were used as part of an undergraduate course entitled Psychology in the Educational Process, a final year option within the Psychology degree programme at Canterbury Christ Church University College. The class consisted of 31 students ranging in age from 20 to 46 years, 27 of whom filled in a post-activity questionnaire.

Procedure

Students first attended a short series of lectures on the psychology of creative learning, covering a range of theoretical models and research findings including those outlined above. They then took part in three seminar sessions over three consecutive weeks, during which they worked individually or in pairs on the following tasks. In session 1, students were provided with basic LEGO bricks and simply asked to build with them (freeplay). In session 2, two constraints were introduced on the *process* of building with the overall objective of transforming the conceptual space; (i) all right-angled joins were prohibited; and later, (ii) in addition to (i) students were instructed to use only one kind of brick. In session 3, constraints were introduced on the *product* by asking students to build each of two structures: (i) a box with a fixed lid that opened and closed; and (ii) a toy with wheels. As once again only basic LEGO bricks were provided, the objective here was to provoke a situation in which successful design solutions were likely to draw upon pre-inventive structures created in the previous session. Hypothetical examples of structures that may be generated within the constraints of session 2 are given in figure 2.

Students were also required to keep a ‘metacognitive diary’ across the three-week period, in which they reflected upon and analysed their own thought processes, feelings and behaviour whilst carrying out the tasks. The diary was intended to facilitate students’ application of theory and their development of metacognitive skills, and also formed the basis of a written coursework assignment.

Evaluation

Following submission of coursework assignments, and prior to receiving feedback and marks, students were given a post-activity questionnaire aimed at eliciting their experience and evaluation of the three seminar

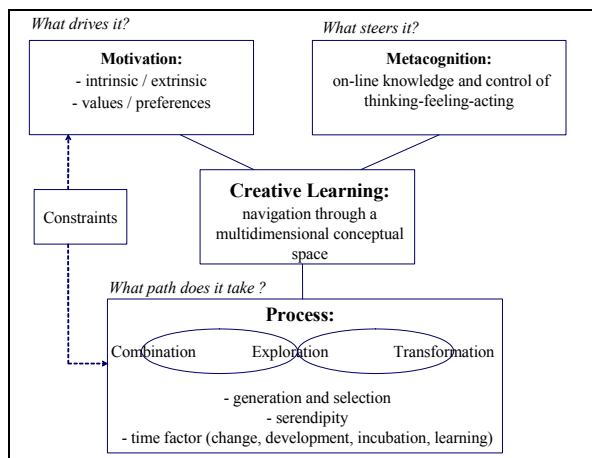


Figure 1
Conceptual framework

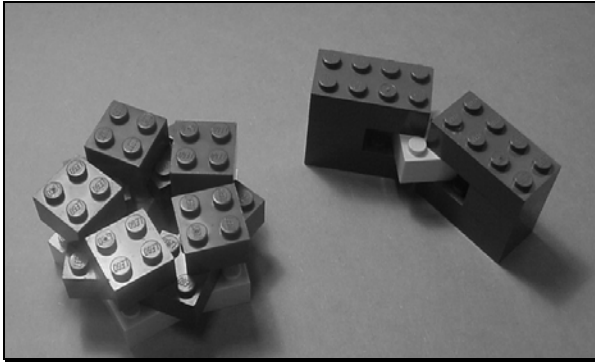


Figure 2

Examples of pre-inventive structures

sessions. The questionnaire comprised a total of 18 questions requiring students to rate the quality and amount of time spent on various aspects of their creative learning across the three sessions using a five-point Likert type scale. The foci of questions were chosen in accordance with the conceptual framework summarized in figure 1, tutor observations made during seminar sessions and the content of students' coursework assignments, addressing the types of structures built, the types of activity engaged in (combinational, exploratory, transformational), motivational changes and self-evaluations of learning outcomes and process.

RESULTS

Types of structure built

Observation during seminars and reading of coursework assignments showed students to be variously concerned with building either recognizable objects (representational structures) or more abstract geometric forms (abstract structures). Figure 3 shows students' self-ratings of the amount of time spent on each kind of structure across the three sessions. While two-way analysis of variance on structure-type by

session showed students to spend significantly more time overall on representational structures ($F=28.29$, $df=1,26$; $p<0.001$), there was also a significant interaction with session whereby more time was spent on representational structures and less on abstract structures in session 3 relative to prior sessions ($F=3.70$, $df=2,52$; $p=0.032$; see figure 3), presumably reflecting the product-oriented nature of constraints introduced in the final session.

Not surprisingly, examination of correlations within each session (S) showed the relative time spent on abstract versus representational structures to be negatively correlated (S1 $r_s=-0.72$, $p<0.001$; S2 $r_s=-0.47$, $p=0.015$; S3 $r_s=-0.58$, $p=0.002$). However, examination of correlations across sessions also found a positive correlation between time spent on representational structures in session 1 and session 2 ($r_s=0.57$, $p=0.002$), and also between time spent on abstract structures in session 1 and session 2 ($r_s=0.55$, $p=0.003$) and in session 2 and session 3 ($r_s=0.61$, $p=0.001$). Such consistency suggests individual students to have been more or less predisposed to building each kind of structure.

Types of activity engaged in

Drawing on Boden's taxonomy of creative behaviour, students were asked to assess their overall pattern of learning experience within and across sessions in terms of combinational, exploratory and transformational activity. Figure 4 shows self-ratings of the relative amount of time spent on each type of activity across the three sessions. Two-way analysis of variance on activity-type by session showed that students tended to engage in more exploratory activity overall, although this just missed significance ($F=2.81$, $df=2,52$; $p=0.069$). However, there was also a significant interaction of activity-type with session such that while exploratory activity remained at a fairly constant level, the amount of combinational activity increased significantly across sessions ($F=3.54$, $df=2,56$; $p=0.036$; see figure 4). In line with the

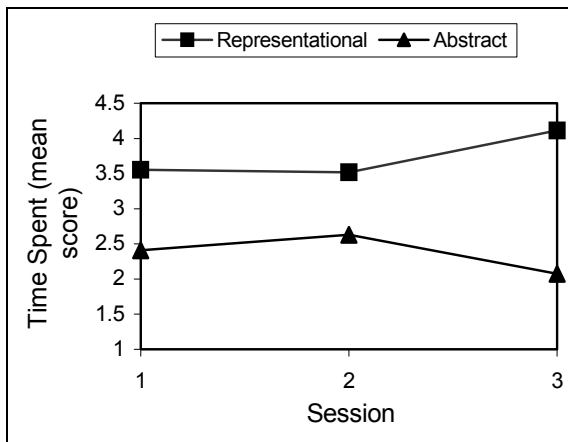


Figure 3

Time spent (in hours) on representational vs abstract forms across sessions

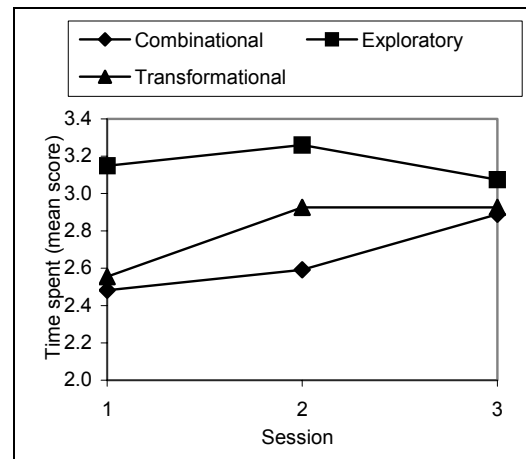


Figure 4

Time spent (in hours) on each type of creativity across sessions

Geneplore model, this suggests that students were combining and recombining the cumulative products of their exploratory activity as the sessions proceeded. This interpretation receives further support from students' self-ratings of the quality of their problem-finding behaviour (figure 5), which also increased significantly across the three sessions ($F=9.58$, $df=2$, 52 ; $p<0.001$).

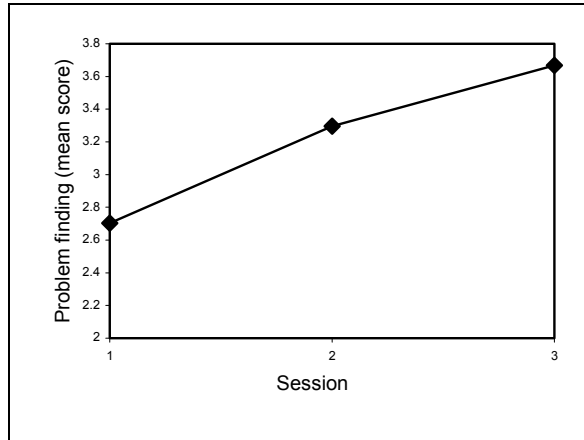


Figure 5

Quality of problem-finding behaviour across sessions

Student motivation

Students were also asked to rate the degree to which they felt intrinsically and extrinsically motivated in each of the three sessions. As can be seen in figure 6, there was a tendency for students to experience more intrinsic than extrinsic motivation in all three sessions, and for both types of motivation to increase across sessions. However, two-way analysis of variance on motivation-type by session found neither effects to be statistically significant.

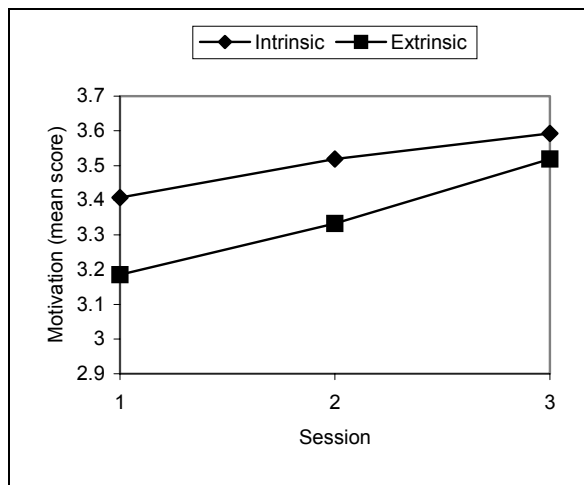


Figure 6

Student motivation across sessions

Examination of correlations also found no evidence for a relationship between the relative amounts of extrinsic and intrinsic motivation experienced within any of the three sessions, suggesting variation in the degree to which these forms of motivation coexisted within individual students. Possible relationships between motivation and the pattern of student learning experiences were also explored through examination of correlations between each type of motivation and time spent on combinational, exploratory and transformational activity in each session. No correlation was found between either form of motivation and the amount of exploratory and transformational activity in any session (as might be expected, given the lack of significant intersessional differences in these forms of activity reported above). However, intrinsic motivation was positively correlated with the amount of combinational activity in sessions 1 and 2 ($r_s=0.40$, $p<0.039$), and to a lesser degree with the perceived success of design solution in session 3 also ($r=0.46$, $p=0.017$; [$r_s=0.34$, $p=0.087$]), whereas extrinsic motivation was not.

In line with existing theory and research, this pattern of results suggests that those students who most clearly exemplified the pattern of learning experience outlined above, in which the cumulative products of exploratory activity are progressively combined and recombined as sessions proceed, were likely to be those who were more intrinsically motivated, and also more likely to create a successful product.

Student evaluation and learning

Table 1 summarises student ratings of the efficacy of the activity in terms of how well they thought the LEGO seminar sessions clarified material covered in lectures, how interesting they found the activity, the degree of insight they felt they had attained into their own learning processes, the effectiveness of the metacognitive diary as a learning tool, and how applicable they thought their findings might be to other areas of their life and study. As can be seen, student evaluation of the activity along all these dimensions was generally very positive, especially so in terms of how interesting they found the activity, and the degree of insight it afforded into their own creative learning process. However, in examining possible relationships

Table 1

Student ratings of the efficacy of the activity		None Slightly Adequate Very Extremely			
Clarification of lectures?			44.4%	55.6%	
How interesting overall?	3.7%		25.9%	51.9%	18.5%
Insight into own learning?		3.7%	18.5%	55.6%	22.2%
Effectiveness of diary?		3.7%	55.6%	29.6%	11.1%
Applicability to other areas?	3.7%		40.7%	44.4%	11.1%

between students' written assignment marks, evaluations and self-reported learning experiences, including types of structures built, patterns of activity engaged in, and motivation, the only relationship found was a positive correlation between the written assignment mark and the reported degree of insight gained ($r_s=0.40$, $p=0.037$).

DISCUSSION

Analysis of the quantitative data suggests that LEGO provides students with a useful conceptual space within which to explore and apply their knowledge of the creative learning process. More specifically, there is evidence to suggest that the series of activities reported in this paper provides students with opportunities to generate and explore pre-inventive structures within a transformed conceptual space, and to combine and recombine these structures in various ways when attempting to solve a given design problem. Furthermore, through reflection on their activity, students gain insight into their own learning processes and motivational tendencies, whilst applying and developing their understanding of the psychology of creativity. The following discussion expands and comments upon these findings.

Generating and exploring pre-inventive structures

As noted above, the pattern of learning experience observed within and across sessions is in accordance with that predicted by the Geneplore model (Finke *et al.*, 1992; Ward *et al.*, 1999). Students' comments in their written assignments, as well as observations by the tutor during class, indicate that the prohibition on right-angled joints introduced in session 2 had the intended effect of forcing students to explore novel ways of combining LEGO bricks that were then incorporated into models built in session 3. Several students reported frustration with difficulties in building caused by the relative instability of structures created in this manner (particularly those who were overly concerned with making representational structures). However, those students who persevered discovered several stable structures, including the ten-point 'star' in figure 2 and various cylindrical forms of hexagonal or other cross-section. Several students felt compelled to transform these structures into recognizable forms such as insects or vehicles through the addition of extra bricks. Others generated a variety of spiral forms through the iterative application of simple combinational rules; an inherently organic process that one student described as 'blossoming'.

Examples of solutions to the 'toy with wheels' and 'box with lid' problems are given in figures 7 and 8, and show how pre-inventive structures such as the ten-point 'star' were recruited and redefined (as 'wheels') in the final session. Interestingly, however, no students discovered the basic 'hinge' structure (figure 2) in session 2, or in session 3, and all solutions to the opening lid relied instead upon a simple swivel mechanism (figure 8). It is highly likely that a greater degree of tutor scaffolding of student problem-solving would have enabled students to better formulate

problems encountered, and increased the likelihood of their discovering alternative pre-inventive structures and solutions. One weakness of the sessions reported here was the relative lack of such intervention, which in hindsight reflected an uncertainty on the part of the tutor over how much to influence students' activity, given that the activity itself formed part of a coursework assessment. In future, the author plans to use the activity as an opportunity for teaching as well as learning, and to include a plenary discussion at the end of each session.

This in turn raises the more general issue of how student experiences during the LEGO sessions impact upon later learning. Within the context of the particular course in which these sessions were embedded, students were directly encouraged to draw upon their own insights and experiences with the LEGO task, together with associated theoretical concepts, firstly when later researching and designing student-led seminars on promoting children's learning in specific domains (mathematics, science, music and so on), and secondly when writing an extended coursework essay. As yet, no formal assessment has been made of students' geneplore activity when carrying out these assignments, and hence whether or not student learning during the LEGO task transferred to other tasks. Informally, however, students' comments during an end-of-course evaluation exercise suggested that they themselves felt such generalization to have occurred; that is, that reflective experience during the LEGO activity facilitated their application of theoretical concepts from the literature on creativity to their own independent learning. Clearly, this is an important area for further research.

Motivational differences

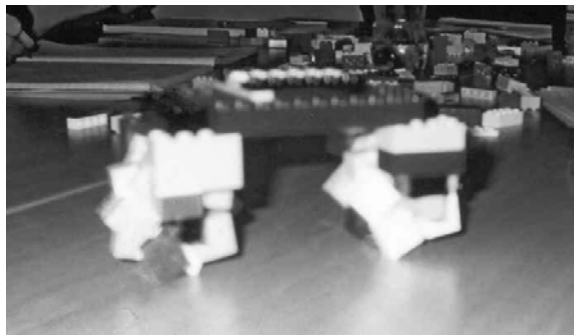
While there is some evidence that those students who were more intrinsically motivated were more likely to experience the geneplore pattern of activity and also more likely to find a successful design solution, obviously no direct causal relationship may be inferred here. It remains uncertain whether intrinsic motivation (and associated enjoyment of the task) is either a cause or an effect of geneplore activity. However, the fact that there was no such relationship with extrinsic motivation, and that students varied in terms of the relative mix of intrinsic and extrinsic motivation, is in line with theories of motivational synergy (Collins and Amabile, 1999) and organismic integration theory (Ryan and Deci, 2000), which predict that extrinsic motivation may either erode or enhance intrinsic motivation according to individual circumstances. Notwithstanding remarks made above on the relative lack of tutor intervention, several students reported experiencing tutor comments made during class sessions, and the fact that photographs were taken, as salient sources of extrinsic motivation. Some felt this to increase their interest in the task, others to interfere with it. Furthermore, it is unlikely that extrinsic motivation was entirely absent from any student's experience, as all students were aware that the activity formed the basis of a written coursework assignment.



(a)



(b)



(c)

Figure 7

Example solutions to the 'Toy with wheels' problem

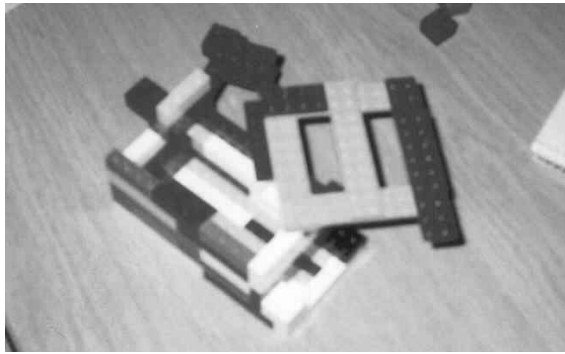
Interestingly, while preceding lectures had covered work by Hennessey *et al.* (1989) showing that prior discussion of the negative effects of reward, and strategies for side-stepping them, was effective in 'immunizing' students against such effects, there was little evidence that students in the current study spontaneously employed such tactics. In future, the author plans to discuss such issues more directly prior to the activity itself.

Further Developments

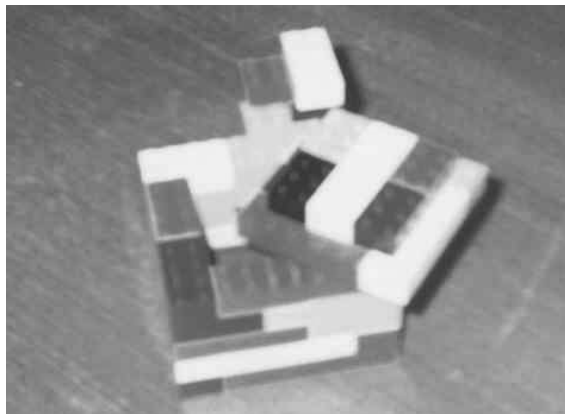
While questions of validity and reliability obviously arise in relation to the use of self-ratings of time engaged in various forms of creative activity, it is important to note that the current study was primarily pedagogically driven and less concerned with testing or elaborating current theory *per se*. In the context of further research, however, an obvious improvement would be to videotape students engaged in the task and compare independent ratings of their activity with self-reports for possible (and potentially interesting) mismatch or agreement. Used in conjunction with a control group and pre- and post-test assessments of understanding, together with formal assessments of transfer as noted above, this would enable firmer conclusions to be drawn about relationships between on-task activity and student learning.

Additionally, it is worth highlighting the fact that most of the research literature on creativity focuses upon individuals, and yet, as in the current study, much activity-based learning takes place in groups. There is now a substantial literature on collaborative learning (for example, Joiner, Littleton, Faulkner and Miell, 2000; Mercer, 1995) and it would seem potentially fruitful to make links between this and the creativity literature in studying and developing creative learning activities. The different emphases and assumptions of these literatures stem from separate origins in cognitive and sociocultural psychology respectively, but as Gauvain (2001) has argued in the context of developmental psychology, much can be gained from their integration. One area in particular that would benefit from such integrated study would be the mediational role of talk in the process of creative learning. In line with methodological improvements noted above, the author is currently pursuing this line of enquiry using video recordings of students engaged in LEGO building activities.

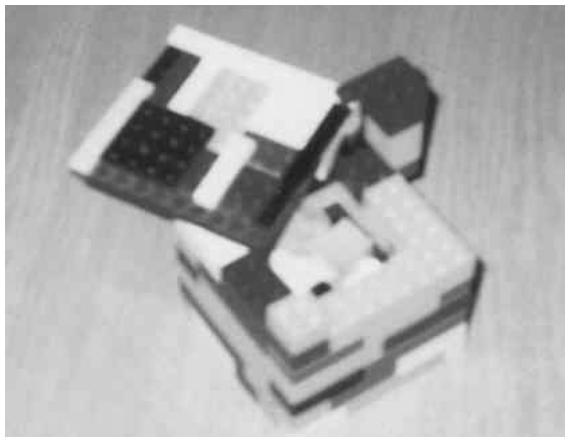
There is also much concern at present over how to promote creative learning in schools (Joubert, 2001; NACCCE, 1999) and the author hopes to undertake a series of studies with primary school children employing tasks similar to those reported in this paper. The author would be interested in hearing from anyone currently working in these, or related, areas.



(a)



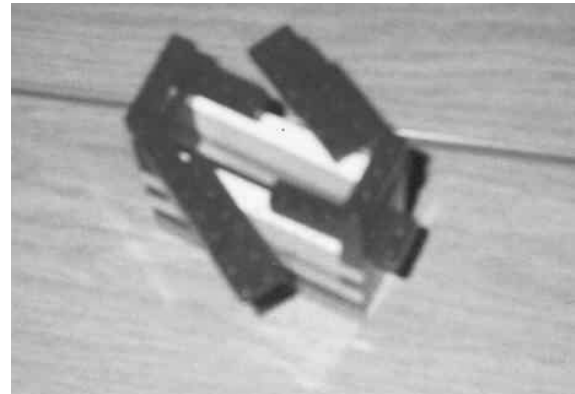
(b)



(c)



(d)



(e)

Figure 8

Example solutions to the 'Box with lid' problem

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