Students’ multi-modal representations of scientific knowledge and creativity

ABSTRACT

The paper brings the results of a project that passed on to students the opportunity for representing their acquired knowledge via the construction of multi-modal ‘learning resources’. These ‘learning resources’ substituted for lectures and books and became the official learning sources in the classroom. The rational for the project was multiple: a. It was expected that the process of re-contextualizing the scientific concepts into students’ lifeworlds, their metaphors and into their everyday language, would benefit both, the creators and the consumers, b. Students were expected to develop multiliteracies in addition to gaining authorship and c. The open and encouraging learning environment that enabled multiple and multi-modal ways of presentation was expected to promote small c creativity to be expressed in the diversified natures of the constructed materials. The results indicate that the stimulating and encouraging environment did promote creative divergence in students’ re-presented products. This was found to be true for Relative Creativity (number of higher creativity products as compared to lower ones), and Diversified Creativity (changing the nature of the constructed product from semester to semester). These materials as learning resources were shown to be as effective as lectures and the construction period was shown to add to students’ knowledge gains. An interesting effect of frontal lectures was found which is attributed to possible different ways of knowledge organization that are induced under different learning conditions.

INTRODUCTION

A common approach to assess creativity is based on the analysis of performance or products created by involved
individuals. The more the product is different from the common and expected within a given cultural-technological context, the more it conveys a non-standard way of thinking or solution, and is regarded as an indication of creative capabilities of the involved individual (Torrance 1979; Smith, 1990; Simonton, 1999; Csikszentmihalyi, 1996). It usually reflects a high level of flexibility, i.e. an ability to address things from different points of view and to get engaged in different strategies and ways of expression. Another dominant factor in the assessment of creativity relates to the flux of an individual's creative products (Torrance, 1979). The conjunction between the two features, of originality and flux of innovative products, is a common measure in addressing creative processes.

The research literature (e.g.: Gardner, 1992, 1993) distinguishes between two major kinds of creativity: ‘Big C’ (C) creativity and ‘small c’ (c) creativity. The ‘big C’ creativity relates to creativity that involves a break through beyond the known and accepted by a given community. Thus, new scientific theories, new ways of plastic expressions, or new technological inventions that lead to dramatic shifts in our cultural and/or professional daily life, all are considered as the manifestations of ‘big C’ creativity. The ‘small c’ creativity refers to behaviors that are judged on localized (contextual) dimensions. It refers to outstanding behaviors of individuals as compared to the productions of their peers. This creativity is comparative in its nature and enables the treatment of behaviors, that on the dimension of ‘big C’ creativity would be considered non-creative, as creative processes. Thomas A. Edison is a good example of an individual that can be described as being blessed with an unprecedented flux of ‘big C’ and ‘small c’ creative products. On the one hand he provided us with the electric light bulb that lighted our homes and on the other hand he has a record of many “smaller” inventions like the talking doll.

Creativity as the expression of flexibility, diversity and imaginative ways of thought is a central objective in educating the youngsters (Carnegie Report, 1986; Moran, 1988). The need to cope seriously with these diversified ways of thinking and create a school culture that advocates and encourages these ways of thought, is essential not only because we wish to develop creative citizens, but as a necessity to cope with the technological developments that dawn on us almost daily. Multiple modalities of presenting knowledge, e.g. visual, auditory, verbal or tactile, all necessitate flexibility of thought that is essential in synthesizing the understandings from the
different ways of knowing and different kinds of knowledge.

However, it seems that these capabilities are very scarce in the educational system. The limitations of the school system to cope with the changes in the conception of knowledge and ways of knowing, prompt researchers to advocate alternative pedagogies to be implemented in the educational system. Thus Langer (1993) advocates the development of “mindfulness” – the ability to address situations from different perspectives as an alternative to the mindless acceptance of frozen and rigid knowledge that is practiced in school. He urges addressing the relevance of knowledge to students’ life, and its dependence on the perspective it was developed within. The concern towards the development of meaningful conceptual understanding that is closer to the world of the learner is also addressed by others, e.g.; Brown, Collins & Duguid (1989) offer situated learning as an alternative to the transmission of abstract decontextualized concepts, Edelson (2001) offers the project Learning-for-Use (LfU) to foster conceptual understanding to be accessible and useful in the future, and Gorodetsky, Keiny, Barak & Weiss (2003) suggest “contextual pedagogy”. It is important to stress that in all of these studies Dewey’s ideas regarding inquiry (1916) and Bruner’s educational approach (1963) that advocates ways of knowing that develop meaningful and innovative ways of knowledge construction by the learner, echo very strongly. These environments encourage self experiencing and diversified ways of knowing that may be the roots for small c or big C creative processes.

Most researchers accept that though creativity is depended on born capabilities it is nurtured by three factors; environment, experience, and knowledge (e.g., Gardner & Boix-Mansilla, 1994; Kerka, 1999; Lavonen et al., 2001).

Environment: An environment that encourages creativity, multi modal expressions, and provides support and appraisal along the creative attempts is likely to support diversified thinking, acquaintance and use of different technologies, and hopefully in the future will lead to ‘big C’ creative processes. Ellermeyer, (1993) claims that children should be encouraged to “doodle” and experiment with new ideas without fear of failing the educational system. Moran (1988) offers some features of a creativity supporting environment, e.g. openness to play, acceptance of child’s ideas, the use of creative problem-solving in all parts of the curriculum, the use of problems that naturally occur in everyday life, and emphasizing process rather than product in learning. Another essential feature in such an
environment is motivation (Amabile, 1985; Osche, 1990). Simonton (1999) and Csikszentmihalyi (1996) add that social recognition of the importance and value of the creative products also enhances creativity. Thus, an environment that not only praises but actually makes use of the creative products of its individuals, will encourage creativity of its individuals. Within the school environment this means that students’ creative products should find their way to the main stream of usable artifacts or ideas and become an essential part of the school daily life.

An environment that promotes creative thinking and exposes the learner to multiple and multi-modal ways of presentation is promoting learners’ confidence to raise innovative ideas and construct imaginative solutions (Byrd & Brown, 2002). Such environments not only enable the expression of inborn creative talents but also encourage creative attempts on the part of average learners. It provides learners with support for innovative attempts and new ways of thinking, tolerates making mistakes, and expresses curiosity and enthusiasm towards innovative ways of expression (Amabile, 1989, 1996).

Creativity also gains from experimenting with new ideas and productions. It is a reciprocal process by which the creative individual and her/his productions are being promoted. The transformation of ideas into artifacts is based on a series of sub-processes the individual has to cope with, that eventually make him an expert in creative processes. Thus creative thinking and creative productions benefit from the experimentation process (Messaris, 2001).

An extensive and deep repertoire of knowledge seems to be essential in creative processes (Amabile 1996; Keegan 1996). Drucker (1985), claims that “knowledge-based innovation is the ‘super-star’ of entrepreneurship”. Taking this idea to the educational system means that creativity will depend on students’ knowledge in different subject matters, their literacy in different modalities of presentation, and capability in viewing problems from different angles or points of view. De Bono’s idea (1973) of encouraging “lateral thinking” and making new connections rather than “vertical thinking” only, can be very helpful in originating new ideas and creativity.

However, the first two factors, an encouraging environment and experience are not common in schools. Most of learning is focused on the study of formal bodies of knowledge transmitted via standardized resources. These resources use the school dominant verbal — written mode and mainly present
the scientific community’s legitimized knowledge. Such a context actually socializes students into a culture whose underlying features are: a. Legitimate knowledge is that which was constructed by scientists, in most cases it is “vertical thinking”; b. Learning is a passive activity whereby the learners absorb the transmitted knowledge from experts, e.g. teachers or books; c. Students belong to the sector that consumes knowledge and does not take part in its construction; d. The verbal modality is the most suitable and appropriate one for dealing with knowledge and knowing; e. The dominant intelligence is the verbal-formal one (though visual elements such as graphs and tables are sometimes employed); and f. Creativity and new ideas or inventions are not part of schooling. On the contrary, success within the school is measured on the basis of the ability to replicate knowledge provided by experts and transmitted via the teachers. Such cultural messages do not provide students with skills for coping with the waves of information resources, e.g. internet, television and other multi-modal communication channels, that demand familiarity and comprehension of different kinds of literacies, e.g. visual, auditory, gestural, spatial, verbal, and multimodal discourses (The New London Group, 1996; Messaris, 2001; McLaren & Hammer, 1995). The school does not encourage students to get knowledgeable with multiple literacies nor in becoming creative users of the different modalities of representation. To participate in such processes of learning students have to acquire multiliteracies that are basic for understanding the multi-modal communicative channels, to be reflective and critical. Paradoxically, not only are students not given the opportunities to develop these present and future needed literacies, but even if they succeed on their own, through out-of-school experiences, to develop a certain level of multi-modal literacies, they find that within the formal school setting, these are useless if not failing. This situation imposes on the educational system a self-defeating gap between the desired and the available. Bridging this gap demands a change in the school pedagogy towards one that provides students with experiential settings towards the mastery of adaptability and flexibility of thought and creativity.

This paper describes a school environment that provided students with the opportunity to explore their interests and intentions and shape their own understandings by re-presenting and re-contextualizing (Van Oers, 1999) abstract ideas into their ‘lifeworlds’ (Gee, 2000 p. 66). Students’ ability to re-contextualize the scientific language into their ‘lifeworlds’ is
an important aspect of scientific literacy as it provides students with the opportunity for bridging between domains of specialists and their own worlds. This environment encouraged the learners to mold their knowledge in multi modal innovative re-presentations, thus by expressing their webs of knowledge through their preferred intelligences (Gardner, 1993).

The environment was structured on our previous knowledge regarding environments that promote self-initiated and self-directed learning (Gorodetsky et al. 2003). The process of re-presentation was structured similarly to guided discovery that encourages "deep, sustained, complex thinking" (Brown & Campione, 1994, p. 261).

Within this environment students were given the responsibility for the construction of multi-modal ‘learning resources’ that were to be used by their peers. Students’ constructed ‘learning resources’, using different modalities, that were to substitute for the teachers’ lectures and the common official textbooks. We felt that students’ engagement in re-contextualizing the scientific concepts into their lifeworlds, their metaphors and into their everyday language, would benefit both the creators and the consumers. Through this process students were to employ and develop multiliteracies in addition to gaining authorship (Semali, 2001) of their re-presented bodies of knowledge, which would gain the school’s acknowledgement as legitimate curricular learning resources. Moreover, the new learners who will use these resources will more easily relate to them and generate better connections among their ‘lifeworlds’, the scientific concepts, and their socio-cultural context. These beliefs guided a science project that involved elementary school sixth graders in the construction and the utilization of learning resource materials prepared by peers.

The setting of the project was a regional community elementary school that catered mainly to a middle to high SES population and that encouraged educational experimentation (Gorodetsky, Koren & Klavir, 2001). It was a highly equipped (e.g. computers) school with a population of teachers and students that comprised a strongly motivated group relative to that of other schools in the region.

The project involved 234 six graders from this school that studied the formal science curriculum that included the themes: power station, light, and the human body. Each student had to choose two of these subjects, one each semester. Meaning, each student studied two subjects during the academic year. The project lasted two years, i.e. it involved two cohorts, each
The project: A 2-day learning program was developed to present a new learning strategy to students. The second cohort of students was divided into two groups: one group received the new learning strategy, while the other group received the traditional learning strategy. The first cohort of students was divided into two groups as well. The first group received the new learning strategy, while the second group received the traditional learning strategy. The first cohort of students was divided into two groups as well. The first group received the new learning strategy, while the second group received the traditional learning strategy.

Table 1. Describes the different learning groups in the classroom and each group received a different learning strategy. The first group received the new learning strategy, while the second group received the traditional learning strategy. The first cohort of students was divided into two groups as well. The first group received the new learning strategy, while the second group received the traditional learning strategy.
<table>
<thead>
<tr>
<th></th>
<th>Cohort 1</th>
<th>Cohort 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 71</td>
<td>N = 65</td>
</tr>
<tr>
<td><strong>Semester A</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The first $\frac{2}{3}$ of the semester</td>
<td>Study one of the themes with a teacher mainly via frontal presentations</td>
<td>Study one of the themes from resources prepared by peers</td>
</tr>
<tr>
<td>The last $\frac{1}{3}$ of the semester</td>
<td>Construction of represented materials</td>
<td>Construction of represented materials</td>
</tr>
<tr>
<td><strong>Semester B</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The first $\frac{2}{3}$ of the semester</td>
<td>Study one of the themes from resources prepared by peers</td>
<td>Study one of the themes from resources prepared by peers</td>
</tr>
<tr>
<td>The last $\frac{1}{3}$ of the semester</td>
<td>Construction of represented materials</td>
<td>Construction of represented materials</td>
</tr>
</tbody>
</table>

This arrangement established a difference between the two cohorts—the first being exposed to science learning from frontal lectures by a teacher (in the first semester) and peer resource materials (in the second one), whereas the second cohort studying only from peer resource materials. In the last third of each semester, students of both cohorts were to construct, in groups or individually, representations of their knowledge in different modalities. They were told that their materials would be used by their peers as learning resources and would substitute for the common textbooks and teachers’ instruction. All students were encouraged to be creative and employ their preferred modalities in re-presenting the scientific concepts. Creativity and individually preferred modalities of expression were advocated and intentionally encouraged via acquaintance to Gardner’s theory of multiple intelligences (Gardner, 1993). The learning process of both cohorts was followed and information regarding the nature of the re-presentations and their impact on students’ knowledge was monitored.

The follow up of the outcomes of learning utilized the following instruments:

The Instruments  
1. A knowledge questionnaire that monitored students’ gains in the specific subject matter theme. The questions in this questionnaire were similar to those in the teachers’ guide.
for the studied themes. This questionnaire was to establish students' knowledge gains. It was administered to the students in the project twice: after studying the theme (about \( \frac{2}{3} \) of the semester) and again after the construction of the re-presented materials (end of semester). An equivalent questionnaire was also administered to a group that was not involved in the project and studied for a full semester with a teacher (mainly frontal lectures).

2. **Students' constructed re-presentations** were classified on the basis of their creativity. The criteria for originality were flexibility and divergence from the common in school. Thus constructed materials that used conventional ways of expression were classified as low creativity re-presentations materials whereas those that were unique (uncommon in the school setting) were classified as high creativity re-presentations. Altogether there were 11 types of re-presented artifacts: crossword, questionnaire, poster, verbal memory game, a written essay, comics, video, power point presentation, concrete model, table game, experiments. These were sub categorized into three categories:

a. Conventional re-presented products. In this category were included products that exhibited low divergence from the common artifacts in school and employed only the verbal modality, e.g. essays.

b. Semi-conventional re-presented products. This category included products that were dominated by the verbal modality but diverged from the common in the school, e.g. crosswords, questionnaires, posters, memory games.

c. Non-conventional re-presented products. This category included products that were further removed from the common ways of expression in the school. These usually made use of different modalities (combinations of verbal and visual ways of expression), e.g. comics, videos, power point presentations, models, table games and experiments.

On the basis of these data the following measures were defined:

a. **Relative Creativity measure:** The production of non-conventional materials was considered to be more creative (graded 3) than that of semi-conventional (graded 2), and the latter more than the conventional (graded 1).
b. **Diversified Creativity:** This was defined as the ability to change the nature of the re-presentation in the second semester as compared to that of the first one. The quantification of this variable was done in the following way: 0 — was assigned when there was no change from one semester to the next in the category of the re-presented artifact; 1 — was assigned when there was a minor change, i.e. the re-presentation in the second semester was different from that in the first semester however it was classified in the same category of creativity, e.g. change from a crossword to a poster; 2 — was assigned when there was a change in the second semester to the highest creativity category (major change), i.e. change from a crossword to a table game; —1 was assigned when there was a negative change, i.e. the student’s re-presentation in the second semester was categorized to a lower creativity category, e.g. change from a table game to a crossword.

c. **Knowledge Grades:** These were students’ grades on the knowledge tests at two points in time: after finishing the learning of a given theme (½ of the semester) and after the construction of the re-presented materials (end of semester). Thus each student had two grades for the study of each theme. The grades are given in percentages.

The research hypotheses were organized under four main categories: A. Relative Creativity, B. Diversified Creativity, C. Knowledge gains, and D. the connection between Knowledge and Creativity.

A. **Relative Creativity**

The hypotheses regarding Relative Creativity were as follows:

1. **Enrolment in an environment that encourages students’ self-expression promotes Relative Creativity:**
   a. The re-presented products will tend towards higher creativity artifacts rather than towards low creativity ones.
   b. Prolonged enrolment in an environment that encourages self expression will promote Relative Creativity in the construction of re-presented products i.e. Relative Creativity in the second semester will be higher than in the first one.
   c. For the same reason the Relative Creativity for the second cohort will be higher than for the first one.
that the teacher's involvement may have some influence. cohort studied in the first semester with a teacher increased the first study was not confirmed and it seemed that the open environment was not constricted, and it seemed that the open environment was more effective than the first cohort. Thus, part (c) of the hypothesis that beyond the second semester (2.65 vs. 2.27), these results indicate that the second cohort exhibited a higher creativity in producing the re-creation of the study. These results also support the nature of the cohort

There was also a main effect for the nature of the cohort

Table 1: The average creativity levels of the students in each semester and the two cohorts.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Total</th>
<th>126</th>
<th>2.35 0.80</th>
<th>2.29 0.87</th>
<th>66</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.95 0.70</td>
<td>126</td>
<td>2.35 0.80</td>
<td>2.29 0.87</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>2.65 0.61</td>
<td>66</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.95 0.70</td>
<td>126</td>
<td>2.35 0.80</td>
<td>2.29 0.87</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>2.65 0.61</td>
<td>66</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results indicate that the average grade for Cohort 2 exceeded that of Cohort 1 on the relative creativity variable for the second semester. The grades are summarized in Table 2.
B. Diversified Creativity

The hypotheses regarding Diversified Creativity were as follows:

2. Time of enrolment in an environment that encourages self expression and creativity promotes the production of artifacts of a diversified nature, meaning, in the second semester students will tend to construct a re-presented product in a more creative mode rather than in a lower creativity mode.

3. A prolonged exposure to an open and encouraging environment will promote Diversified Creativity, i.e. the students from the second cohort will exhibit a tendency to produce higher-level creativity products in the second semester as compared to those of the first one.

Table 3 provides the distribution of the changes in students’ re-presentations.

A non-parametric X² analysis that was done on the row of the ‘total’, confirmed that beyond cohorts the re-presented artifacts in the second semester were of a higher creativity (X² = 9.85 d.f. = 3 p < 0.05). Meaning, 61% of all of pupils made positive changes, whether minor or big and only a minority of students regressed to a product of a lower creativity (14%). These data support hypothesis 2 claiming that in the second semester students’ re-presented products will be on a higher level of creativity.

<table>
<thead>
<tr>
<th></th>
<th>A negative change</th>
<th>No change</th>
<th>A minor change</th>
<th>A major change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohort 1 (teacher in first semester)</td>
<td>4</td>
<td>9</td>
<td>28</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>27%*</td>
<td>33%</td>
<td>67%</td>
<td>49%</td>
</tr>
<tr>
<td></td>
<td>7%**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cohort 2</td>
<td>11</td>
<td>18</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>73%</td>
<td>67%</td>
<td>26%</td>
<td>43%</td>
</tr>
<tr>
<td></td>
<td>22%</td>
<td></td>
<td>35%</td>
<td>20%</td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>27</td>
<td>38</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>14%</td>
<td>25%</td>
<td>35%</td>
<td>26%</td>
</tr>
</tbody>
</table>

* Percentage from column  ** Percentage from row
A $X^2$ analysis that was performed on the other two rows of Table 3, indicated that the two cohorts exhibited a different Diversified Creativity ($X^2 = 15.57$ d.f. $= 3$ p < .05). The students of the first cohort, that studied with a teacher for $\frac{2}{3}$ of the first semester, exhibited a higher tendency towards change in the second semester; i.e. more of them made a major change in the re-presentations (28% vs. 23%). A similar tendency is observed for a minor creativity change; the first cohort students performed 2.5 times more frequently a minor change than those of the second cohort (49% vs. 20%). Moreover, in the second cohort the percentage of the students that made no change or made a negative change in the re-presented products was higher than in the first cohort. These results seem to indicate that the first cohort that studied with a teacher in the first semester exhibited a higher level of Diversified Creativity in re-presenting their knowledge than the students that were exposed to an entirely open environment. These results do not support the third hypothesis.

C. Knowledge gains.

The hypotheses regarding knowledge gains were the following:

4. Students learning in a multi-modal environment utilizing multiliteracies will gain more knowledge than students learning via frontal lectures.

5. Students that were involved in the process of constructing re-presented materials will gain from this learning process.

For the analysis of these hypotheses the knowledge gains of three groups that learned the theme “Power Station” under different conditions was analyzed. Group 1 studied with a teacher for $\frac{2}{3}$ of the semester and prepared re-presented materials during the last $\frac{1}{3}$ of the semester. Group 2 studied from re-presented materials prepared by their peers for $\frac{2}{3}$ of the semester and prepared their own re-presented materials during the last $\frac{1}{3}$ of the semester. Group 3 studied only with a teacher during the entire semester and was not involved in the project. All groups studied the subject “power stations” for one semester, however their exposure to frontal teaching was different; group 1 was exposed for $\frac{2}{3}$ of the semester, group 2 was not exposed to any frontal teaching on the “power station”
subject and group 3 was exposed only to frontal teaching. The mean knowledge grades of the three groups at the end of the semester are provided in Table 4.

A one way ANOVA was performed on these data, the dependent variable being the knowledge grades at the end of the semester and the independent variable being the 3 groups. The differences between the groups are significant only with the extension of $p = 0.10$ [F(2,176) = 2.70, $p < .07$]. This result indicates that the average grades of all the three groups are quite similar. The results indicate that though the open environment did not promote learning it did not inhibit it. A Post-Hoc LSD analysis indicated that there was no significant change between the grades of group 3 and group 2. However, there were significant differences between the grades of group 3 and group 1 ($p < .03$) and between the grades of group 1 and group 2 ($p < .03$). The results indicate that the group that learned with a teacher and was involved in the construction of re-presented materials achieved the most.

For groups 1 and 2 the contribution of the preparation of the re-presented materials to the final semester grades was analyzed. A General Linear Model with repeated measures on the achievement grades of these groups after $\frac{2}{3}$ and the entire semester, was performed. A main effect for the construction process was found [F(1,79) = 36.022; p < 0.001], indicating that students’ grades after constructing re-presented materials were higher than those before (75.73 vs. 71.85). Though no significant main effect for the nature of the cohort was found, there was a significant interaction [F(1,79) = 5.67; p < 0.05] between the nature of the cohorts (group 1 and 2) and students’ achievements before and after the construction of re-presented materials. This result indicates that group 1 (that studied with a teacher for $\frac{2}{3}$ of the semester) gained differently from the construction.

**TABLE 4.** Average knowledge grades of three groups at the end of the semester on the theme “Power station”.

<table>
<thead>
<tr>
<th>Nature of group</th>
<th>Average grade</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (cohort 1)</td>
<td>80.90</td>
<td>10.76</td>
<td>22</td>
</tr>
<tr>
<td>Group 2 (cohort 2)</td>
<td>74.08</td>
<td>12.37</td>
<td>59</td>
</tr>
<tr>
<td>Group 3</td>
<td>74.39</td>
<td>13</td>
<td>96</td>
</tr>
</tbody>
</table>
process. Though students' grades after \( \frac{2}{3} \) of the semester were similar (70.55 and 69.61 for group 1 and 2 respectively) the students in group 1 improved more than those of group 2 (80.91 vs. 74.08, see Table 4). To clarify the nature of the interaction a paired t-test on the grades of both groups before and after the process of construction, was performed. It was found that for group 1 students' average grade before (70.55) and after the construction (80.91) was significant \([t = 4.39 \text{ d.f.} = 21 \ p < .001]\) and similarly for group 2 (69.61 vs. 74.08, \([t = 3.65 \text{ d.f.} = 58 \ p < .01]\)). As both groups improved significantly the interaction can be attributed to the higher improvement of group 1 as compared to group 2. The different behavior of both groups can be attributed to the teacher's involvement in group 1.

D. The connection between Knowledge and Creativity.

The hypothesis relates to the connection between creativity and knowledge.

6. *Students that produce higher levels of creative represented products will gain more knowledge.*

For the analysis of hypothesis 6 a two way General Linear Model with repeated measures was conducted on the data in Table 5. This table includes students' grades in all the themes they studied. The dependent variable on which the repeated measures were applied were students' grades of knowledge before and after constructing the materials. The independent variables were as follow: a. The nature of the cohort (cohort 1 studied partly with a teacher and cohort 2 without); and b. the levels of the Relative Creativity expressed in the re-presented products. It was found that preparing re-presented materials had a main effect \([F(1,207) = 46.19 \ p < .001]\). No main effect was found for the cohort. These results indicate that regardless the source of learning from, teacher or students' prepared materials, the construction of re-presented materials leads to better learning (higher grades at the end of the semester as compared to those after \( \frac{2}{3} \)). In addition it was found that the Relative Creativity measure had a main effect \([F(2,207) = 6.07 \ p < .01]\).

A Post–Hoc LSD analysis indicated that there was a significant difference between the knowledge level of students that constructed conventional and semi-conventional materials \((p < .001)\) and those that constructed non-conventional products \((p < .001)\). There was no significant
TABLE 5. The average knowledge grades before and after the construction of re-presented products for the two cohorts (with and without a teacher during the first 2/3 of the first semester) and the levels of Relative Creativity of the re-presented materials.

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Relative Creativity level</th>
<th>Number of pupils</th>
<th>Average knowledge grade</th>
<th>s.d.</th>
<th>Average knowledge grade</th>
<th>s.d.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Knowledge grades after 2/3 of the semester</td>
<td></td>
<td>Knowledge grades at the end of the semester</td>
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difference between the grades of students that constructed semi-conventional and non-conventional materials.

The results confirm that students with low grades tended to prepare conventional materials and those with high grades tended to prepare non-conventional ones. This phenomenon may indicate that creativity is dependent on knowledge – the higher the student’s knowledge she tends to be more creative than one with less knowledge. Thus it is possible that creativity is not promoting of learning but is dependent on knowledge. To address this possibility additional analyses regarding the following questions were performed:

Was students’ knowledge after the construction of materials influenced by their knowledge rather than creativity or the nature of the cohort they were part of?
a. A three-way ANOVA was performed with the dependent variable being students’ grades (knowledge) after the construction of the learning materials and the independent variables being the nature of the re-presented products, the nature of the cohort (the first cohort being exposed to frontal lectures in the first semester and the second one learning only from students’ prepared materials), and students’ grades before the construction process. A main effect of the knowledge before construction on the grades after construction was found \([F(50;212) = 4.69 \ p < .001]\), meaning, high knowledge promotes even higher knowledge. No main effect for the nature of the re-presented product or the cohort was found. However a significant interaction was found between the latter \([F(2;212) = 3.49 \ p < .05]\). In a Post-Hoc LSD analysis for each cohort it was found that for the first one there is no significant difference in students’ knowledge that chose the different ways of re-presenting materials. However for the second cohort a significant difference in knowledge between those that chose to re-present knowledge in a conventional way from those that chose to prepare semi-conventional \((p < .001)\), and from those that chose to prepare non-conventional materials \((p < .001)\), was found. Thus in the case of cohort 2 it seems that choosing to prepare any kind of creative re-presentation is not only dependent on knowledge but also influences the knowledge gains from the process of re-presenting.

b. A similar analysis as the above but this time the dependent variable was creativity, i.e. the nature of the re-presented materials, and the independent variables being knowledge (grades before and after the construction of materials) and the cohort, was performed. From the analysis a significant main effect of knowledge on creativity (the levels of Relative Creativity) was found \([F(48;2.12) = 2.28 \ p = .052]\), meaning that the higher students’ knowledge before the construction of materials the more creative the re-presentation was. A main effect for the cohort was also found \([F(1;212) = 4.89 \ p<.05]\). The average creativity grade for the first cohort was 2.65 and for the second one 2.23. There was also a significant interaction between the cohort and average knowledge grades \([F(5;212) = 4.67 \ p < .05]\). These
results indicate again that creativity is dependent on students’ preliminary knowledge and the nature of the cohort they were part of.

DISCUSSION

The purpose of this research was to study the influence of an open environment that encourages students’ creativity in re-presenting scientific knowledge, on the nature of these products and possible gains in scientific knowledge. This environment encouraged the use of multiple modalities including technological devices. Intertwining technology into students’ daily school work was encouraged to create real life creative settings they will function in, in the future (Ward et al., 1999; Masterman, 1985). The environment provided learners with opportunities for creative expressions of their acquired knowledge through multi modal re-presentations, and on the other hand it also encouraged students to utilize such productions as learning resources. The research results describe the effect of such a stimulating environment on the creative expressions and gains in knowledge of the involved students.

The results support the expectation that a stimulating and encouraging environment will promote creative divergence in students’ re-presented products. This was found to be true for Relative and Diversified Creativities as described above. These results actually confirm the view advocated in the educational literature that open, encouraging and supportive environments are essential for creative processes (Lavonen et al., 2001; Torrance, 1977). It seems that students’ prolonged time of experimentation in such an environment, enhanced their creative re-presentations. The results indicate an increase in the amount of non-conventional re-presentations that were constructed by the students after two semesters as compared to that after one semester. This result is in line with claims that creativity is an acquired capability and can be learned and/or fostered, as advocated by Higgins (1994) and de Bono (1973).

Even more, it seems that actual experimentation in constructing creative processes has a synergetic effect. Thus students’ products in the second semester (their second production) included more non-conventional products as compared to those after the first semester. This is in line with Lewis et al.’s (1998) claim that creativity stimulates further creativity. Creative productions act as emotional stimulants (Torrance, 1989), as well as cognitive learning (Messaris 2001) tools towards the enhancement of creativity.

The failure to confirm hypothesis number three regarding
the differences between the two cohorts on creativity actually poses an interesting issue. The general a priori assumption of this work was that the wider the exposure to creative representations the greater the effect would be on creative products. However, it was found that actually the first cohort that had a narrower exposure to multi-modal creative artifacts (they studied 2/3 of the first semester with teachers) were more creative than the second cohort that studied only from multi-modal representations. This difference was observed for Relative as well as for Diversified Creativity. Actually this result supports claims that creativity is knowledge dependent. Only on the basis of the needed knowledge can creativity thrive (Stonecipher, 1998; De Vries & De Long, 1999). It is possible that structured bodies of knowledge as presented in teachers' lectures ease students in initiating creative attempts. Whereas, when students learned from divergent sources they had first to restructure these bodies of knowledge into a coherent structure and only then to get involved in creative processes. Feldhusen (2002) stresses that coherent knowledge bases are essential in all thinking processes including creative thinking. Declarative and procedural knowledge seem to be essential prerequisites in creative processes though the mechanism by which these bodies of knowledge function is not yet understood (Scott 2000). Thus we believe that the exposure to formal instruction that provided students with coherent bodies of subject matter was supportive in creating diversified re-presentations. The structured bodies of knowledge worked as anchors for creativity and divergence. The possible absence of structured bodies of knowledge as a result of exposure to multimedia re-presentations is a concern expressed by Birkerts (1995) and Stoll (1995) that warn us about some problems associated with the digital information environments, that include extensive exploration at a superficial level. It is possible that this result actually strengthens the teacher's position within the classroom. As claimed by Leu (1996) it is possible that the new technologies actually enhance the teacher's role in orchestrating students' learning.

Another aspect of the creative re-presentations related to students' knowledge gains from learning from these resources as compared to learning from teachers and from the process of construction. The results do not provide a decisive answer about which learning environment (from teachers or representations) is advantageous. There was no significant difference between students' achievements after learning in these
environments (hypothesis 4). In a way this result is actually encouraging as the students that learned from their peers re-presentations seemed not to be in a disadvantaged position. Another encouraging point is that the process of constructing re-presentations actually contributes significantly to students’ knowledge. Thus students’ achievements after the process of re-presentation was higher than before. This, again, brings to mind the notion of reciprocity between knowledge and creativity. As mentioned before knowledge seems to influence creativity and here it seems that creativity enhances knowledge.

The quantitative results in this paper do not reflect students’ attitudes and enjoyment in this environment. We will try to compliment the paper with some qualitative sayings by students. The freedom to choose the sources for learning or the medium for constructing the re-presentation seemed to be valued by students. They seemed to enjoy the freedom of choice, (“You have much more choice . . . more humor . . . and more freedom”) and the language that is similar to theirs, (“They (materials) are more suited to our level and they speak in the everyday language whereas in the books they speak in a not so comprehensible language”). The re-presented knowledge seemed to be closer to them (“In learning materials prepared by the students you have their personal knowledge . . . and also their opinion”). And yet, they felt the responsibility for high level materials (“You approach it seriously because somebody has to learn from it”). Along this process they actually felt that they were recreating knowledge (“...here you make the staff”).

REFERENCES


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