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The role of design-principles in designing courses that promote collaborative learning in higher-education

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A B S T R A C T

Design-patterns and design-principles represent two approaches, which elicit design knowledge from successful learning environments and formulate it as design guidelines. The two approaches are fairly similar in their strategies, but differ in their research origins. This study stems from the design-principles approach, and explores how learning is affected by curriculum-materials designed according to two main design-principles: (a) engage learners in peer instruction, and (b) reuse student artifacts as resource for further learning. These principles were employed in three higher-education courses and examined with 385 students. Data analysis was conducted in two trajectories: In the “bird’s eye view” trajectory we used a “feature” unit of analysis to illustrate how learning was supported by features designed according to the two design-principles in each of the courses. In the “design-based research” trajectory we focused on one feature, a web-based Jigsaw activity, in a philosophy of education course, and demonstrated how it was refined via three design iterations. Students were required to specialize in one of three philosophical perspectives, share knowledge with peers who specialized in other perspectives, and reuse the shared knowledge in new contexts. Outcomes indicated that the design in the first iteration did not sufficiently support student ability to apply the shared knowledge. Two additional design-principles were employed in the next iterations: (c) provide knowledge representation and organization tools, and (d) employ multiple social-activity structures. The importance of combining several design-principles for designing curricular materials is discussed in terms of Alexander’s design-pattern language and his notion of referencing between design-patterns.

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1. Introduction

Many higher-education institutions offer hybrid courses, which combine face-to-face with online instruction. Research shows that this combination has the potential of promoting learner-centered, active and collaborative learning (Barab, Kling, & Gray, 2004; Dori & Belcher, 2005; Linn, Davis, & Bell, 2004; O’Donnell, Hmelo-Silver, & Erkens, 2006; Roschelle, Pea, Hoadley, Gordin, & Means, 2000; Salomon & Ben-Zvi, 2006; Stahl, 2006). The literature refers to learner-centered instruction as one that supports learners in knowledge-building by promoting higher order thinking skills, collaboration, product-construction, and reflection (Cobb, 1996; Collison, Elbaum, Haavind, & Tinker, 2000; Dori, 2003; Ewing & Miller, 2002; Lazarowitz & Hertz-Lazarowitz, 1998; Resnick, 1996; Rovai, 2000).

In spite of the potential benefits in using hybrid courses for fostering socio-constructivist learning, many instructors use their course websites mainly for administration, accessibility to course materials, and online submission of assignments. Learning in

most cases remains traditional; a teacher-centered transmissionist model is employed, rather than taking advantage of the technology to apply a learner-centered constructivist model, and instructors tend to focus on content rather than on the learning processes (Herrington, Reeves, & Oliver, 2005). A recent NRC report about undergraduate instruction in science, technology, engineering and math (McCray, DeHaan, & Schuck, 2003) documents even more convincingly than past reviews, that instruction based primarily on lectures fails to help students develop conceptual understanding. They claim that “for many students the traditional didactic lecture, when applied as the primary instructional method in science courses, fails to provide opportunities for integrating new and old knowledge. Lectures may lead to memorization of factual information but often do not succeed well in eliciting comprehension of complex concepts.” (p. 26). To describe the current situation in undergraduate instruction, Herrington et al. (2005) use the term “information industry” and claim that universities fail to focus on their role as educational institutions.

The most important factor which influences the adoption of socio-constructivist pedagogies at any grade-level, with or without technology, is the instructor (Howard, McGee, Schwartz, & Purcell,

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2000; Maor & Taylor, 1995). However, even when an instructor is aware of, and willing to implement such pedagogies, designing curriculum-materials that take advantage of the web to support these pedagogies is far from obvious. It is clear that to support socio-constructivist learning, instructors are required to do more than simply upload learning materials to the course website. They should carefully design features that engage learners in active learning, and that build on peer learning – a huge resource, usually neglected in traditional higher-education instruction (Herrington et al., 2005; Kali & Ronen, 2008). To support instructors and other course designers in developing such curriculum-materials, it is important to formulate design guidelines that build on research and document success stories as well as failures, and to provide examples that illustrate how these guidelines can be expressed as features in hybrid courses. A relatively new line of research which typically yields design guidelines is design-based research (Barab & Squire, 2004; Collins, Joseph, & Bielaczyc, 2004; Dede, 2005; The Design-Based Research Collective., 2003). In the sections below we describe how design guidelines are elicited from design-based research, and how these guidelines can be formulated as design-principles and design-patterns.

1.1. Using design-based research for eliciting design guidelines

Curriculum development, whether supported by the web, or not, is based on epistemological views of the designers. Designers have ideas about how learning takes place, that stem from a theory or perspective on learning. They have epistemological assumptions about the nature of knowledge in a specific scientific domain. In addition, a good design process is sensitive to the needs and requirements of the users. A needs-analysis stage is therefore an important preliminary step in any curricular design process (Dick, Carey, & Carey, 2001; Ronen-Fuhrmann, Kali, & Hoadley, 2008). This stage is usually followed by a careful trial and refinement process, until the learning goals of the designed curriculum are met. To draw conclusions from these studies, researchers compare and contrast multiple versions of the curriculum (Barab & Squire, 2004; Collins et al., 2004; The Design-Based Research Collective, 2003). Design-based research is an emerging methodology for synthesizing the lessons learned from this trial and refinement process. This type of knowledge is sometimes referred to as design knowledge – knowledge about successes and failures of using any curricular innovation in real classroom setting. Design-based research studies contribute to what we know about how people learn. They also widen the body of design knowledge available for future curriculum development.

To make this body of knowledge useful for curriculum designers, researchers have sought to abstract general guidelines that are based on large numbers of studies, and can assist curriculum designers to make thoughtful design decisions (Avgeriou, Papasalouros, Retalis, & Skordalakis, 2003; Brown, 1992; Herrington, 2006; Merrill, 2002; Mor & Winters, 2007; Quintana et al., 2004; van den Akker, 1999). In general, two main approaches have guided researchers in creating these sets of guidelines, the first is the design-patterns approach, and the second, is the design-principles approach. Both approaches seek to identify and document the key ideas that make a good system different from a poor system, and to assist in the design of future systems. The ideas expressed in design-patterns as well as in design-principles are intended to be general enough to be applied in very different context, but still specific enough to give constructive guidance. The two approaches are very similar regarding their goals and strategies, but have yielded different terminology since they have grown from different research origins. We provide a brief review of these approaches and their origins in the following sections.

1.2. The design-patterns approach

The design-patterns approach stems from the monumental work on the design-pattern language initiated by Alexander, Ishikawa, and Silverstein (1977). In the book the timeless way of building (Alexander, 1979), the pattern language is applied for designing buildings and towns. However, the pattern language can lend itself to any design field, including curriculum design. Researchers who adopted the design-patterns approach (e.g. Avgeriou et al., 2003; Mor & Winters, 2007) usually adopt the general construct of a design-pattern including: short name, description of context, the problem statement, explanation and examples of the solution, and further references to other patterns.

Recently, a somewhat different use of the term design-patterns was made by Linn and Eylon (2006) who refer to a design-pattern as a sequence of activities in a curriculum, followed by teachers and students in a classroom. They describe ten design-patterns that research has proved to promote knowledge integration. Kali and Linn (in press) show how such design-patterns and design-principles can complement each other in a design process. The patterns help designers in generating sequences of activities, and the principles assist them in designing features that build up each of the activities in the sequence. In the remainder of this article, we refer to the term design pattern as described by Alexander et al. (1977) and their followers.

1.3. The design-principles approach

The design-principles approach stems from the design experiments research trajectory, initiated in the early nineties by Brown (1992). These experiments were the ancestor of the design-based research methodology described above. At the same period, Collins (1992), called researchers to refer to education as a “design science”. He based this notion on Simon’s (1969) famous book, which identifies various professions, such as architecture, engineering, computer science, medicine, and education with the sciences of the artificial.

The design-principles approach uses ‘design-principles’ as an organizational unit for synthesizing design knowledge (Brown, 1992; Brown & Campione, 1996; Collins et al., 2004; Herrington, 2006; Kali, 2006; Linn, Bell, & Davis, 2004; Merrill, 2002; Quintana et al., 2004). Bell, Hoadley, and Linn (2004) describe design-principles as:

“...an intermediate step between scientific findings, which must be generalized and replicable, and local experiences or examples that come up in practice. Because of the need to interpret design-principles, they are not as readily falsifiable as scientific laws. The principles are generated inductively from prior examples of success and are subject to refinement over time as others try to adapt them to their own experiences” (p. 83).

1.4. The Design Principles Database

Based on this approach, the Design Principles Database (Kali, 2006; Kali & Linn, 2007) was developed to capture, coalesce and synthesize design knowledge. The database (<http://design-principles.org>) is a public mechanism to support researchers and curriculum designers to share their design knowledge in the form of design-principles, exemplified by descriptions of features from learning environments. Participants are invited to publish, connect, discuss and review design ideas, as well as use these ideas to design new curricula. The database builds on

the knowledge-integration framework, which captures design knowledge from 20 years of research (Linn & Hsi, 2000; Linn et al., 2004). Since its initiation in 2001, the database has grown with contributions from participants in workshops, from course activities, and from the public. The current entries in the Design Principles Database represent the contributions of over 60 individual researchers. Most of the researchers contributed new features that employ design-principles in the database, and showed how these features affect learning in new contexts. In this manner, researchers who contribute features to the database strengthen the design-principles they connect them with (Kali, 2008). The database includes about 100 features (mainly from physical, life, and earth sciences), connected with several dozen design-principles. Each design-principle provides a general rationale, theoretical underpinning, and important considerations, such as pitfalls, tradeoffs and limits of practical use, to help designers benefit from the many example features it is connected with in the database. Although the database stems from the design-principles approach, the hierarchical structure of the database, the connections between design-principles in various levels and between principles and example features, and the constructs that make up a design-principle, follow the spirit of Alexander's (1979) design-pattern language. In this manner, the Design Principles Database merges between the design-principles and design-patterns approach. Recent research has shown that the database can (a) promote collaborative knowledge building for communities who design and explore educational technologies (Kali, 2008), and (b) assist novice designers in creating effective technology-based curriculum units (Ronen-Fuhrmann et al., 2008).

1.5. Goals of the current research

The current entries in the Design Principles Database describe mainly features from K-12 learning-environments. Therefore, and to respond to the challenges described above regarding the gap between research and practice in higher-education instruction, the goals of the current research were: (a) seek for common rationales that have guided the design of three successful hybrid courses in higher education and formulate these rationales as design-principles, (b) illustrate how the specific features in each course employ these design-principles, (c) explore the effect of these features on student learning, (d) refine the design-principles based on the findings and contribute the refined principles to the Design Principles Database for the general use of the public, and (e) explore the role of design-principles in a design process.

We start by describing the three courses, focusing on two main design-principles, which were identified as common rationales for their design: (a) engage learners in peer instruction, and (b) reuse student artifacts as resource for further learning. We then describe two trajectories in which we explore the role of design-principles in designing hybrid courses that promote socio-constructivist learning: a "bird's eye view" and a design-based research trajectory. We continue by using these trajectories as a framework to present our findings. In the bird's eye view trajectory we illustrate how learning was supported by features that employ the two design-principles in each of the courses. In the design-based research trajectory we focus on one feature from one of the courses, a web-based Jigsaw activity, and demonstrate how it was refined via three design iterations. Finally, based on the findings of the current research, we discuss the role of design-principles and design patterns in guiding a design process. We conclude that although such guidelines play a crucial role in curriculum design, they should be referred to with certain modesty, keeping in mind the important role that iterative refinements play in any design process.

2. Courses design

The three hybrid courses that were chosen for this study are courses that were designed, and taught by the authors of this article, and took place at the Department of Education in Technology and Science at the Technion. These courses have typically been highly rated in student feedback surveys, and have continued to score high throughout the current study. A description of each of the courses follows.

2.1. Course 1: philosophy of education

The objective of this course is to help undergraduate students construct an educational philosophy that would lead them as educators or as educational researchers. All the course meetings are conducted face-to-face. The course website guides students through group-activities, some conducted at class-meetings and some, designed to take place in between the meetings. Course activities are built around three dimensions: (a) a theoretical dimension, in which learners study relevant literature and discuss ideas in the area of educational philosophy, (b) a "school inquiry" dimension, in which learners analyze and assess one school they select from a given list of "interesting schools", and (c) the "ideal school" dimension, in which learners apply knowledge gained through the other dimensions by designing and presenting a conceptual model of a school that represents their own educational perspectives.

2.2. Course 2: learning and instruction in online courses

This course, designed for undergraduate and graduate students, focuses on theoretical and practical aspects in online learning and instruction in a socio-constructivist approach. The first few weeks are taught online and are devoted to community-building and discussion on students' initial perceptions about online learning. In the second part of the course, students work in groups to build their own online "mini-course", which focuses on one issue about online learning and instruction which they specialize in (e.g., creating a sense of a community, the role of the teacher, supporting metacognitive processes, etc.). In the final part of the course students study each others' mini-courses, taught by their peers, provide feedback to each other, and reflect on the whole process.

2.3. Course 3: assessment of educational projects

The objective of the course is to provide graduate students with tools that will endow them with initial preparation as future assessment experts in science and technology education. The course includes face-to-face meetings and online forum discussions. Students read a diverse collection of articles on assessment. Every two weeks one pair of students is responsible for leading an online discussion about one of the articles. Each student is assessed via multidimensional assessment tools based on: (a) her/his contribution to the online forum discussion both as leader and participant, (b) presentation of the summary in class, including a comparison with two other articles, and (c) a final project based on the biweekly articles that all the students read. The students are involved in developing the assessment criteria and their implementation in the course.

When we examined the three courses described above, we found that two main rationales were common to the design of all three courses. These rationales, which stem from a socio-constructivist view of learning, were formulated as two design principles. A short description of each of the principles, as they initially ap-

peared in the Design Principles Database follows. The specific contribution of this study to these principles is described in the outcomes of the design-based research. More information about each of the principles, and connections to features from learning environments that are not part of this study can be found in the database.

2.4. Principle 1: engage learners in instruction of their peers

This principle calls for creating opportunities for students to serve as instructors of their peers. Playing the role of the instructor, whether the learners are a small group, or the whole class, and whether the instruction is done individually or in peer-teaching, has many advantages. Peer-instruction activities, when designed appropriately, can encourage students to deepen their understanding of contents, become more attentive to ideas brought up by peers, take responsibility of their own learning, increase motivation, and enhance metacognitive skills (Topping, 1996). Students who can reflect on their way of thinking and learning can set up learning goals and carry them out, choose appropriate learning strategies, and supervise their advancement towards achieving these goals (Linn & Hsi, 2000).

2.5. Principle 2: reuse student artifacts as resource for further learning

This principle advocates the use of artifacts developed by learners, as resources for further learning of their peers (Dillenbourg, 2002; Ronen, Kohen-Vacs, & Raz-Fogel, 2006). In this manner, the artifacts, created by individuals, or in groups, can support the learning of those who struggled to interpret and process a certain body of knowledge, as well as others, who can benefit from the products of this process (Bransford, Brown, & Cocking, 1999). Scardamalia and Bereiter (1994) argue that environments that support the development of a knowledge-building community, enable learners to share knowledge and artifacts, so that this knowledge becomes part of the environment, and other learners can build on and further advance this knowledge. They refer to such supports, in which the classroom community works to produce a collective product as second-order environments. They distinguish these environments from first order environments, in which the knowledge produced by learners is “merely a summary report of what is in individual minds”.

In the following sections we describe how features in each of the courses employ these two design principles. This description is also summarized in Fig. 1. A feature in this study refers to the design of any element that supports learning (e.g., an assignment that

guides students in creating presentations of “a day in a student’s life” in their ideal school, in course 1; guidelines for using appropriate “voice and tone” when instructing an online course, in course 2; an assignment that scaffolds students in self-assessment, in course 3). It is important to note that each of the features was designed in an iterative design process through which features considerably changed. We describe here only the final versions of each of the features. Further on in the article we describe the evolution of one feature through this iterative design process, and the lessons we learned with regards to student learning on one hand, and how to better design features to support learning on the other.

2.6. Features employing the two design-principles in course 1

One of the ways we employ the *engage learners in instruction of their peers* design principle in the *philosophy of education* course is in a web-based Jigsaw activity for studying three philosophical perspectives (feature 1a in Fig. 1). The final version of this feature consisted of three successive stages. (a) In the first stage students acquire knowledge in specialization groups – each individual takes part in a specialization group, which studies, via literature reading and discussion in a forum, one philosophical perspective. (b) In the second stage all the students in the class collaboratively create a wiki table from contributions of individuals and groups – at this stage the individuals return to their home-groups as experts in one perspective, and are responsible to teach this perspective to other members of their group. Each group is now responsible to fill the contents of one row in the wiki table, which synthesizes one aspect in each of the perspectives. As a result a table with the whole class shared knowledge, exemplified in Fig. 2, is obtained. (c) In the third stage, students are invited to edit and refine contributions of their peers in the wiki table.

To deepen students’ understanding of the three philosophical perspectives, we designed another feature in the course, in which students are required to apply the shared knowledge created by the whole class in the wiki table (feature 2b in Fig. 1). In this feature, students are required to use this shared knowledge to analyze the “interesting school” they were studying. By creating this opportunity for students to use the collaboratively constructed wiki table for another purpose, we apply the *reuse student artifacts as resource for further learning* design principle.

2.7. Features employing the two design-principles in course 2

To *engage learners in instruction of their peers*, the main assignment in the course *learning and instruction in online courses*, was

Course Name	Principles	Engage learners in instruction of their peers	Reuse student artifacts as resource for further learning
Philosophy of education	Features	1a- Web-based jigsaw activity	1b- Analyze a school
Learning and instruction in online courses		2a- Design, develop and instruct a mini-course	2b- Study aspects in online learning via mini-courses
Assessment of educational projects		3a- Peer instruction of assessment topics	3b- Assessment of a specific educational project

Fig. 1. Application of the two design principles via features in the three courses.

	Philosophical Perspective 3: Essentialism	Philosophical Perspective 2: Progressivism	Philosophical Perspective 1: Existentialism	
Aspect 1: Goals of education	Contribution of expert student to Aspect 1	Contribution of expert student to Aspect 1	Contribution of expert student to Aspect 1	Contribution of group A to the class Product
Aspect 2: Instructional methods	Contribution of expert student to Aspect 2	Contribution of expert student to Aspect 2	Contribution of expert student to Aspect 2	Contribution of group B to the class Product
Aspect 3: Role of the teacher	Contribution of expert student to Aspect 3	Contribution of expert student to Aspect 3	Contribution of expert student to Aspect 3	Contribution of group C to the class Product
Aspect 4: Student responsibility	Contribution of expert student to Aspect 4	Contribution of expert student to Aspect 4	Contribution of expert student to Aspect 4	Contribution of group D to the class Product
Aspect 5: Contents	Contribution of expert student to Aspect 5	Contribution of expert student to Aspect 5	Contribution of expert student to Aspect 5	Contribution of group E to the class Product
Aspect 6: Educational system	Contribution of expert student to Aspect 5	Contribution of expert student to Aspect 5	Contribution of expert student to Aspect 5	Contribution of group E to the class Product

Fig. 2. Whole-class collaboratively constructed wiki table with example student contributions.

to design, develop and instruct their own two-week mini-course (feature 2a in Fig. 1). Using step by step instructions on the course-website, each group first studies the contents of their mini-course (issues in online learning and instruction) by reading and discussing relevant literature, then they design activities for instruction of these contents, and finally they teach (online) their mini-course to the rest of the class. The mini-courses created in this process serve as a resource for other students' learning of the mini-course's contents. In this manner, the second design principle is employed – students' artifacts are reused for other students' further learning (feature 2b in Fig. 1). Our rationale was that knowing that their mini-courses would serve as the only resource for other students to learn about their mini-course contents, students would be motivated to produce thoughtful artifacts.

2.8. Features employing the two design-principles in course 3

One of the main features in the *assessment of educational projects* course is an activity that takes place throughout the course, in which pairs of students are responsible to teach a topic about assessment to the rest of the class (feature 3a in Fig. 1). They first study the topic with the rest of the class, using a pre-assigned list of articles. Then they lead an online discussion; they pose introductory questions in the forum, and are responsible for facilitating the discussion. Finally, they create a summary of the online discussion, upload it to the course website, and present it during a face-to-face meeting. Using contents from additional references which they are responsible to find, they are expected to deepen the dialogue. In this manner the design principle *engage learners in instruction of their peers* is employed in the course.

Another feature in the course is the final course project, in which students are required to assess an educational project using all the resources created in the course (feature 3b in Fig. 1). One of the resources for the project is the online discussions and the summaries, which are the outcomes of the features described above. Here again, the *reuse artifacts as a resource for further learning* is employed. We assumed that these artifacts would serve valuable resources for students' final projects, and complement the professional literature, because they involve negotiation of knowledge which all students were part of.

3. Methods

To provide a broad perspective of the role that design-principles play in the design of hybrid courses that promote socio-constructivist learning, our analysis is conducted in two trajectories. In the first trajectory we seek evidence showing how learning was supported by features that employ the two design-principles in each of the courses. This trajectory provides a "bird's eye view", in which findings from application of design-principles in multiple contexts (the three courses), strengthen these principles. Using multiple contexts as corroborations for design-principles has been shown a productive means for supporting design-based research (Kali, 2008). In the second trajectory, we describe how features in one of the courses evolved through an iterative design process. In this trajectory, a design-based research methodology is used to explore student learning with the feature, and to acquire design knowledge with regards to the design principle employed in the feature. The unit of analysis, the data sources, and the general data analysis techniques are similar in both trajectories. However the samples were different, as described below. In both trajectories, a

Table 1
Enactments, iterations and number of students in the three courses.

Course	Philosophy of Education (1)	Learning and instruction in online environments (2)	Assessment of educational projects (3)	
Semester				
Fall 03	80 (22 groups)	none	12	
Spring 04	29 (10 groups)	32 (9 groups)	11	
Fall 04	35 (10 groups)			
Spring 05	36 (9 groups)	16 (6 groups)	12	
Fall 05	24 (8 groups)			
Spring 06	25 (7 groups)	19 (6 groups)	none	
Fall 06	33 (8 groups)			
Spring 07	21 (7 groups)			
Total	283	67	35	385

Legend:

- Iteration 1
- Iteration 2
- Iteration 3

mixed methods approach (Ercikan & Roth, 2006) was used to support the findings.

3.1. Sample

This research is part of a larger design-based research study conducted between the years 2003–2007 with a total of 385 students, which explores student learning in the three courses described above, and examines how this learning relates to a larger set of socio-constructivist design-principles (Levin-Peled, 2008). The findings reported in this article refer to a set of this sample as follows. In the bird's eye view trajectory, to explore the effect of features, after they have been refined, we use samples that include only the last iteration in each course (we use the term iteration to refer to a sequence of enactments in one course in which features remained constant) (Table 1). Consequently, in this trajectory the samples include 161 students (103 from course 1; 35 from course 2; and 23 from course 3). In the design-based research trajectory, we focus on the iterative design process of features from the philosophy of education course: the jigsaw activity and the analysis of schools activity. Therefore, the sample includes 283 students who studied the course in all the iterations of the course (Table 1).

3.2. Data sources

The main data source in both research trajectories was the rich set of artifacts created by students, as individuals or groups in each of the courses. Some of these artifacts were created on the course site, using tools such as wikis and forums, and others, such as Office documents were uploaded to the course sites. To support our analysis of student artifacts, we also conducted Likert-type and open-ended surveys in each of the courses, which required students to reflect about their learning with regards to the use of various features in the courses. We also conducted interviews with about 10% of the students in each of the iterations in courses 1

and 2, and with about 50% of the students in course 3. In these interviews we asked students to reflect about the ways specific features contributed (or not) to their learning.

3.3. Data analysis

The unit of analysis in this study is a feature; meaning the effect of a single feature in a single course on student learning. Using this unit of analysis was possible since we collected artifacts created by students for each feature, which enabled us to analyze students' "understanding performances" (Gardner, 1991; Perkins, 1992) as expressed in each of these artifacts. To do that we had to develop specific rubrics to analyze each type of understanding we wanted to probe in the various artifacts. Following Chi's (1997) framework, the rubrics enabled us to quantify student performances. For example, see Table 2, which describes the rubric we developed for analyzing one type of students' artifacts in the philosophy course.

We would like to note that assessing the effect of a specific feature on learning, in our use of "feature" as a unit of analysis, is a common methodological strategy in design studies. For instance, Linn, Lee, Tinker, Husic, and Chiu (2006) show how specific visualization features enhance students' knowledge integration of complex science topics. Another example illustrates how refinement in the design of a specific peer-assessment feature brought to considerable improvement in students' performances in assessment (Kali & Ronen, 2008).

To increase the validity of our findings we sought to triangulate different types of evidence to support any claim we make about the effect of a feature in a course on student learning. For each feature we initially analyzed students' understanding-performances. The criteria used to assess each artifact are described in relation to each of the findings. We then came up with an assumption about the learning that took place using this feature. Finally, we sought corroborations to this assumption using other data resources. Another strategy to increase the validity of our findings using the "feature" unit of analysis was by enacting an iterative design process, and examining the effect of changes we made in the features' design on student learning (see the design-based research trajectory below).

3.4. The design-based research trajectory

Design-based research methodology, as described above, typically involves an iterative design process, which explores how learning is affected by design features, and how lessons learned from each iteration affects the design. In this way design-based research provides a unique lens for exploring learning, as well as for yielding design knowledge, which can be translated into design guidelines (Barab & Squire, 2004; Collins et al., 2004; The Design-Based Research Collective, 2003).

To explore the effect of the jigsaw activity, three iterations were conducted (Table 1). Each iteration included enactment of the course, data collection and analysis, and refinements to the features based on the findings. Each iteration enabled us to make conclusions about collaborative learning in hybrid courses, as well as to better design the features for the next iteration, and

Table 2
Rubric for analyzing the level of application of the shared knowledge in a new context—students were required to analyze the philosophy of a school using three philosophical perspectives (Essentialism, Progressivism, and Existentialism).

	Low level (1)	Intermediate level (2)	High level (3)
Argument for affiliating school philosophical perspective, and Justification of argument based on observations and activities	Artifact shows lacks in understanding or incorrect analysis of school characteristics and philosophical perspective	Partially correct philosophical categorization, based on laconic justification	Deep understanding and correct philosophical categorization based on well-supported evidence and a variety of presentation modes

to contribute design knowledge to the Design Principles Database, as described in the findings and the discussion and conclusions sections.

4. Findings

To provide the reader with a general view of how features that were designed with the two socio-constructivist design-principles supported learning in the three courses, we start by describing outcomes from the bird's eye view trajectory. We then continue with describing outcomes from the design-based research trajectory, which provide a deeper insight to the way learning is affected by a single web-based feature, and how the design of the feature can better employ a design principle by employing multiple design principles.

4.1. The bird's eye view trajectory: how features supported learning in the three courses

In this section we describe findings from different data sources which indicate how learning was supported by final versions of features in each of the courses, which were designed according to the design-principles: *engage learners in instruction of their peers*, and *reuse student artifacts as resource for further learning*.

4.1.1. The effect of the "web-based jigsaw" activity

In order to examine the effect of the web-based jigsaw activity (feature 1a in Fig. 1) on student understanding of the three philosophical perspectives, we analyzed the quality of the collaborative wiki tables created by students. The quality of the table represents the class's distributed understanding (Salomon, 1993) of the nuances in each of the philosophical perspectives according to the various aspects, and therefore depicts their understanding of these perspectives. We assessed this quality by comparing the information in each of the table cells to a reference table created by the instructors. The analysis indicated that the information constructed collaboratively in each of these enactments (four enactments of the final iteration, with $N = 103$) was very similar to the reference table. Specifically we scored the tables as 97.0% correct in fall 05; 99.0% in spring 06; 89.0% in fall 06; and 98.0% in spring 07. It should be noted that this stage of the activity, in which students were required merely to summarize the reading in a table, does not require higher-order thinking skills (Dori, 2003; Resnick, 1996; Zohar & Dori, 2003). Therefore, the high scores are not surprising. Our challenge was to find ways to assist students in applying this knowledge in a new context, as described in the "design-based research" trajectory. However, this finding does indicate that the process of learning a philosophical perspective in a specialization group, and then having to teach this knowledge to peers in the home group, and having the responsibility of creating knowledge for the whole class in the collaborative wiki table, supported student acquisition of knowledge, at least at a declarative level.

Another outcome that indicates that the collaborative table was a productive support for student learning was received from the survey. Mean values of answers to questions about the jigsaw activity, which was added to the survey at the 7th and 8th enactment of the course, indicate that students ($N = 54$) perceived all 3 stages of this activity, as a great contribution to their learning: for the construct acquiring knowledge about the three philosophical perspectives in specialization groups, a mean value of 4.5 of 5 ($SD = 0.7$) was obtained; for sharing the specialization knowledge with peers in home groups, $M = 4.3$ ($SD = 0.7$); for learning from peers about their specialization contents, $M = 4.3$ ($SD = 0.8$); and for using the wiki table as a resource for other course assignments, $M = 4.5$ ($SD = 0.7$).

4.1.2. The effect of the "design, develop and instruct a mini-course" activity

To evaluate the effect of the process of designing and teaching the mini-courses on student learning about theoretical and practical aspects in online instruction, we analyzed this process and the final artifacts in three aspects: (a) students' *understanding of the contents* (as reflected in each group's online discussion about the course-contents during the process of designing the mini-courses), (b) the *design of activities* (to what extent activities supported the contents and a socio-constructivist approach and were clear and inviting), and (c) the *quality of instruction* of the courses (the extent to which instructors were attentive to their learners' emerging needs, in terms of supporting them in understanding procedures, comprehension of contents, and collaboration with other learners).

Since the feature only changed slightly in the second enactment, and since no significant difference was found between the two enactments regarding the quality of mini-courses, we merged data from the two enactments of the course (total of $N = 35$, number of groups = 12). Outcomes indicate that the mean values for the three aspects were as follows: *understanding of contents*, 91.7% ($SD = 14.5$), *design of activities* – 86.4% ($SD = 11.3$), and *Quality of instruction*, 93.3% ($SD = 9.9$). The rather high variance can be explained by the fact that participants were a mix of undergraduate and graduate students. However, the high mean value, indicates that the quality of the mini-courses developed by students was high for the analyzed aspects, meaning that the feature supported students' learning, especially of practical aspects in online learning and instruction.

These findings were strengthened by the analysis of the survey conducted in the two enactments in this iteration. Here again, no significant difference was found between the two enactments, which enabled us to refer to the merged sample ($N = 35$) as one entity. The survey revealed that students perceived the mini-courses as a great contribution to their learning. In a scale of 1–5, the construct *Reading and discussing the literature in preparation for designing the mini-course*, received a score of $M = 4.8$ ($SD = 0.5$), *Design and development of the mini-course*, $M = 4.8$ ($SD = 0.5$), and *Instruction of the mini-course* $M = 4.7$ ($SD = 0.5$).

Evidence to the type of learning that took place in this process can be found in responses to a general open-ended question in the survey. In these responses students explained in which manners the design of the mini-courses contributed to their learning. For instance, one student said "it was a great experience to instruct the mini-course, we had to deal with many issues such as, what to do when the learning takes different directions than we planned, how do we support participation, how do we refer to posts in the forum which we do not agree with".

4.1.3. The effect of the "peer instruction of assessment topics" activity

To assess the impact of this feature (feature 3a in Fig. 1) on student learning, we used two rubrics, one for assessing how students led the online discussion, and the other, for assessing how they led the face-to-face discussion. The *criteria for leading the online discussion* included: (a) posing questions that require higher order thinking skills, (b) attentiveness to peers, (c) processing and elaboration of the discussion by providing intermediate summaries, and (d) voice and tone that invite collaboration and foster a good atmosphere in the discussion. The *criteria for leading the face-to-face discussion* included: (a) the quality of the online discussion summary, (b) oral presentation of discussion and of further reading in an academic standard, and (c) clarity, flow and originality in presentation.

We refer to the sample as $N = 23$, comprised of graduate students in two enactments of the course (no significant differences were found between student performances in those enactments). The analysis indicates that grades for this specific feature were extremely high; using the criteria mentioned above, the mean score for leading the online discussion was 98% ($SD = 3.0$), and the score

for leading the face-to-face discussions was 93% (SD = 4.3). In order to express such high performances, students had to gain deep understanding and knowledge in the assessment area, and acquire leadership skills that are highly important for their careers.

Retrospective interviews, which were conducted about a year after the course ended, indicate that students perceived the fact that they were required to take the role of an instructor in the course as a highly enriching learning experience. In many of the interviews the issue of responsibility and motivation, which were fostered by playing the instructor's role, were mentioned. For instance one student says "I knew that in the moment of truth I will need to instruct part of the course. It gave me a great motivation. . . I felt that the challenge is greater than understanding; I also had to think how to make the contents interesting for others. Our responsibility for the success of the course was one that is higher than usually given in other graduate courses". The high motivation and responsibility brought students to become more critical and thus deepen their understanding of the contents. For instance, another student says "Serving as an instructor forced me to think deeper about the article, to ask myself questions and to find unresolved issues", or "Playing the role of the instructor is the thing I remember most from the course. I remember very well all the nuances of the contents that I was responsible for teaching. This is knowledge that I can retrieve from my mind at any relevant time". Another student noted that "the course provided me with inspiration and guidance about how to construct a new course for my high-school students in industry and management department". It is also important to note that having students play the role of the instructor involved putting them in a certain degree of anxiety, but that students saw this stress eventually as positive. For instance, one student said "This was a difficult period for me due to the high pressure I was in. I almost left the course, but was encouraged to stay, and today I am very thankful for that!"

4.2. The design-based research trajectory: how to improve learning by refining features to better employ principles

In this section we describe how the jigsaw activity feature, which was described above in its final version, was developed through three iterations in the design-based research study. The findings from each iteration, and comparison between them, provide an invaluable understanding of how features affect learning. It enables to pinpoint the exact elements of the design which were successful or unsuccessful in supporting student learning. This lens also enables drawing conclusions regarding the design-principles employed by the features. Specifically, it enables to identify challenges and tradeoffs in designing according to a design principle, and to suggest possible solutions to overcome these challenges.

We start by describing the general structure of the activity, which stayed constant throughout the whole study. We then describe the design of each iteration, the outcomes from its enactment, including confirming and challenging outcomes, and design decisions we made according to these outcomes. For each iteration we compare outcomes with previous iterations.

4.2.1. General structure of the jigsaw activity

The jigsaw activity described above in its final version with the wiki table, consisted from its initial version, and throughout the iterative design process, of three stages: (A) knowledge acquisition in specialization groups stage (the three philosophical perspectives discussed in online forums); (B) knowledge sharing in home groups stage; and (C) knowledge application in a new context (analysis of the "interesting school", this stage is described as feature 1b in Fig. 1).

Stages A and C did not change throughout the design process. The reason for keeping stage A constant was that this stage, in

which students acquire knowledge in specialization groups about each of the philosophical perspectives was successful from the beginning. The level of discussions in all eight enactments was high. Discussions were assessed using a rubric of 1–7 (7 – deep, original contribution/reference to several key ideas in text/peers; 6 – relevant contribution/reference to several key ideas in text/peers; 5 – one original contribution/reference well explained; 4 – one original contribution/reference poorly explained; 3 – repetition of idea already made by others; 2 – shallow response, sometimes refers to a marginal aspect of text; 1 – shallow response that doesn't indicate reading of the text). Outcomes indicate a mean of 6.1 (SD = 1.3) for students in all iterations (N = 285). No significant differences were found between the enactments or iterations with regards to this stage.

The reason for keeping stage C (application of shared knowledge in a new context) constant was that it enabled us to assess students' understanding of the three educational perspectives. As described below, outcomes from this stage were unsatisfactory in the first iterations and improved only following considerable modifications to the design of the knowledge sharing in home-groups stage B.

4.2.2. First iteration: unstructured knowledge sharing

In the first iteration, the knowledge sharing in home-groups (stage B) was conducted in the following manner: after students specialized in one philosophical perspective, we devoted about half an hour from the class meeting for students to gather in their home-groups and orally explain the three philosophical perspectives to each other. Following this period, students were required to continue their group work (in home groups) on analyzing their "interesting" school, and apply this newly acquired shared knowledge in their analysis.

To assess these group-artifacts, we created a rubric to depict low, intermediate and high levels of application of the knowledge about the three philosophical perspectives in the context of analyzing schools (see Table 2). The outcomes showed that the application of the shared knowledge in this iteration was low in 40.9% of the groups' artifacts, intermediate in 27.3%, and high, only in 31.8% (Fig. 3). These outcomes were also strengthened by informal discussions we had with students. Several students complained that they find it difficult to understand the differences between the three educational perspectives, and that their understanding of the two philosophical perspectives that they haven't studied is low. These findings clearly indicated that the unstructured knowledge sharing strategy was not sufficient in supporting students in acquiring robust knowledge about the three educational perspectives.

4.2.3. Second iteration: structured knowledge sharing

To support students in acquiring more robust knowledge about the three philosophical perspectives in the knowledge sharing stage, we decided to provide them with a tool that would help them represent the individual knowledge each of them has gained in the first stage, and organize it as shared knowledge. In terms of design-principles, this employs two other design-principles from the Design Principles Database, namely, *provide knowledge representation tools*, and *employ multiple social activity structures*. The first principle calls for providing learners with tools in which they can visually represent, at different learning stages, their understanding of scientific ideas. Linn et al. (2004) claim that knowledge representation tools can promote interpretation and theorizing about evidence. The second principle calls for creating multiple opportunities for students to combine individual, group and whole-class activities. In such activities the intellectual properties of each individual shapes the group's knowledge-building process. The group's knowledge-building process, in turn, shapes the individual's intellectual properties. The atmosphere created is of seri-

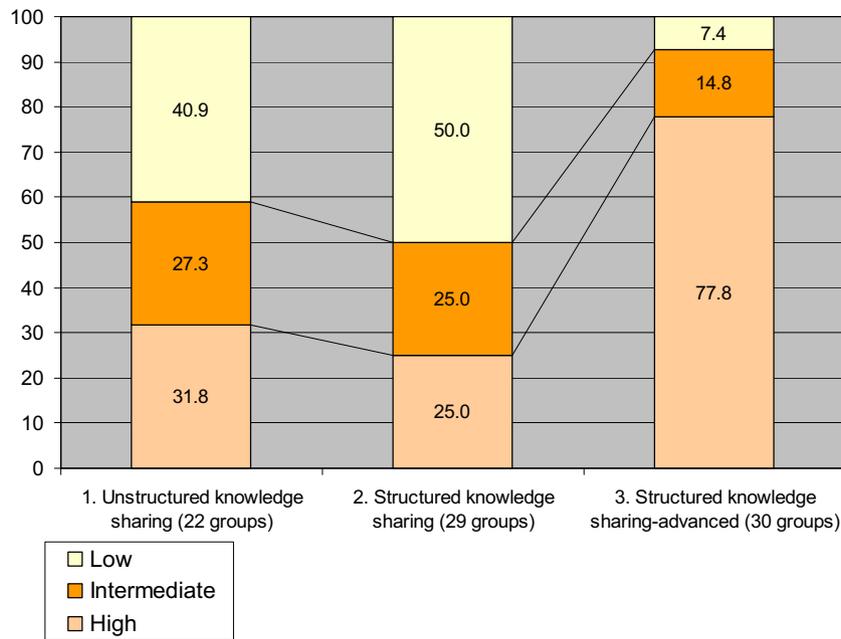


Fig. 3. Comparison between the levels of application of the shared knowledge in the three iterations.

ous engagement in problem solving which acknowledges ideas of all students and enabling each one to be part of the group's solution (Salomon, 1993).

The tool we used in this iteration to assist students to represent the knowledge each one of them gained in the specialization groups, and organize it as shared knowledge, was a simple table, similar to the one presented in Fig. 2. In contrast to the final version of the feature described in Fig. 2, in this iteration the table was not yet designed using wiki technology. It was a Word document, in which each group was required to fill in one row, and upload as attachment to a forum. At the end of the process a volunteer student combined all the attached documents into one table and uploaded the document back to the forum.

The outcomes from this iteration were still disappointing. Analysis of the group-artifacts, in which students were required to apply their shared knowledge in a new context (i.e., the analyze an "interesting" school activity) indicated that the application of the shared knowledge was low in 50.0% of the groups, intermediate in 25.0%, and high, only in 25.0% (Fig. 3). In comparison to the first iteration, these findings show that there was no improvement in student outcomes in this iteration, indeed, there was even a slight regression.

However, when we analyzed the quality of the tables in the enactments involved in this iteration, using the reference table described above, we found that they were very high: 93.2% in spring 2004, 97.3% in fall 2004, and 95.1% in spring 2005. Our interpretation was that the high-quality information gathered in the tables represented the high level of distributed knowledge of the whole class, but that this shared knowledge was not held by each of the individual students, which made it difficult for them to apply it in a new context.

Based on this finding, we decided that the problem in the design in this iteration was not in the notion of structuring per-se. Rather, we assumed that we needed to find better ways to employ the two design-principles: *provide knowledge representation tools* and *employ multiple social activity structures*. When each group worked on their row in the table in a Word file, they could not easily view what the other groups, who were working on other aspects of the three philosophical perspectives were writing. In terms of multiple social activity structures, they combined their

work as individuals with their work in small groups, but they did not have an easy opportunity to employ the whole-class social activity structure.

Another factor which might have prevented students to internalize the shared knowledge about the philosophical perspectives was that only when all groups finished their work, the final table was uploaded as an attachment to the forum. As an attachment, this document was somewhat hidden in the course website, and accessibility to this valuable information was somewhat cumbersome. We postulated that students would be able to better benefit from the contents of the table, if this information would be made more accessible to all groups while they contribute their own rows to the table, and afterwards, when required to apply the contents of the table in a new context.

4.2.4. Third iteration: structured knowledge sharing – advanced

To better employ the two design-principles: *provide knowledge representation tools* and *employ multiple social activity structures*, we decided to design the knowledge sharing stage in the third iteration as a wiki table, as described above in Section 2.

The analysis of the group-artifacts, in which students were required to apply their shared knowledge in a new context showed great improvement compared to the two previous iterations; the application of the shared knowledge was high in 77.8%, intermediate in 14.8%, and low only in 7.4% of the groups. Fig. 3 shows the comparison between the levels of application of the shared knowledge in the three iterations.

The large percentage of artifacts representing high level application of the shared knowledge in the third iteration was also evident in richness and creativity in types of artifacts students constructed, which we did not find in the first and second iterations. Students used various combinations of narrative, tabular and graphic representations to illustrate the ways the schools they visited implement various levels of the three philosophical perspectives (see for example Fig. 4).

We believe that the great improvement in students' ability to apply the shared knowledge stemmed from the wiki technology, which better employed the two design-principles *provide knowledge representation tools* and *employ multiple social activity structures*. This claim can be supported, as mentioned above in the

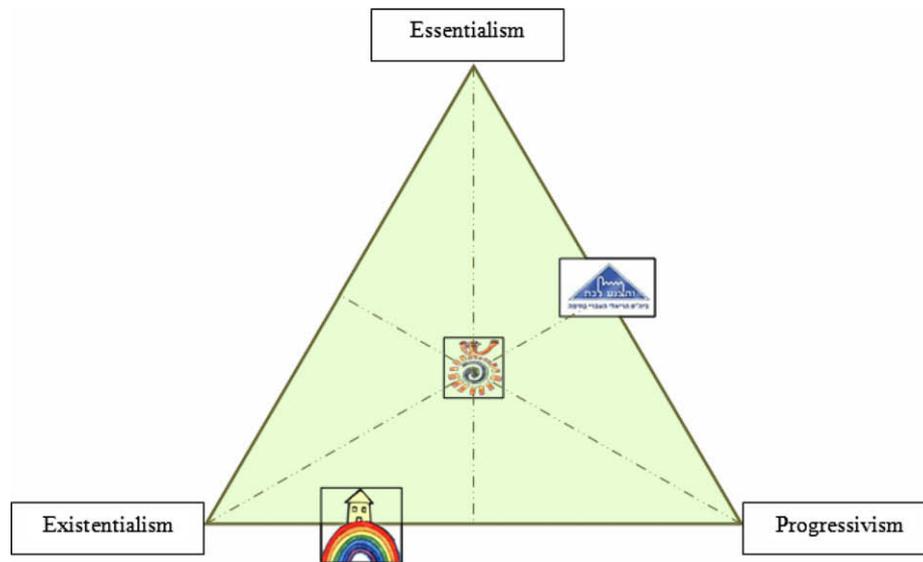


Fig. 4. Artifact with a high-level analysis. The icons represent three schools, and their location in the diagram represents the degree to which each of the three philosophical perspectives is represented. The figure was accompanied with accurate justifications based on the knowledge in the wiki table.

“Bird’s eye view trajectory”, by the survey results, which indicate that students’ perceived the wiki table as a productive means for supporting their learning ($M = 4.5$ of 5.0).

In its wiki format, the table enabled students to view information contributed by their peers while they were working on contributing their own information, and to easily identify overlaps and gaps, refine their contribution appropriately, and thus gain better understanding of nuances that distinguish between the three philosophical perspectives. These processes are indicated by many written comments made by students in the open-ended survey. For instance, one student wrote “Editing of the wiki table contributed a lot. . . it enabled us to improve our descriptions step by step. . . Seeing what others wrote in the table was very helpful for comparing [between schools]¹ and for deciding which [philosophical] perspectives are represented. The openness and accessibility of the wiki table was also an important factor in students’ use of the knowledge represented in the table while analyzing their school. As indicated by comments such as: “the table was very easy to use – we opened it every time we needed this information, it became a great resource”.

Additionally, using the wiki technology, we enabled students to edit each other’s contributions to the table. Although this was not a mandatory assignment, many students adopted it and edited each others’ entries. The editing was usually in terms of better articulation, addition of examples etc. There were no major changes to ideas originally contributed by other groups. Interestingly, the editing even continued a long time after the Jigsaw activity was over, indicating students’ enthusiasm from this activity. The editing of the table as a whole enabled students another opportunity to employ multiple social activity structures, moving between the individual, the group and the whole class. This might have increased students’ ownership of the contents in the table and brought to the larger adoption of the shared knowledge by individuals. This was indicated by students’ comments such as “It [the table] was a summary, created and refined by all of us, of everything we learned about the three philosophies, I use it for assignments in other classes as well”.

5. Discussion and conclusions

At the beginning of this article we described two approaches, the design-principles and design-patterns approaches, which seek to synthesize design knowledge and articulate it as guidelines that would assist curriculum designers to build on past successes and failures. This research shows that we should refer to these guidelines with certain modesty. Whether supported by design guidelines or not, a design process would always require an iterative design process. The design-based research of the Jigsaw activity illustrates this clearly. Although the design-principles *engage learners in instruction of their peers* and *reuse artifacts as a resource for further learning* were employed in this activity from the beginning, only after a careful analysis and successive refinements to this activity, it was successful in supporting students to develop the deep understanding that we sought. The modifications that were made in this activity (providing the table that assisted students to organize and represent their knowledge, and helped them build their own knowledge with relation to the group’s knowledge and the class knowledge) represent a better employment of the two design-principles, which originally guided the design. In other words, the iterative design process seemed to have an essential impact in developing a successful feature even though it was originally designed to employ the design principles.

That said, we would like to stress the crucial role that design-principles played in the iterative design process in the current study. Too often curriculum designers, especially those who design technology-based curriculum materials, get carried away by wanting to design “cool” features, which are sometimes not aligned with a sound pedagogical rationale. Salomon and Ben-Zvi (2006) describe this situation as having the technology tail wiggle with the pedagogy body. Ronen-Fuhrmann et al. (2008) describe it as feature-based design rather than rationale-based design. The refinements that were made in the current study to the Jigsaw activity were driven directly by seeking ways to better employ the design principles. Without these rationales we would not have had a leading direction for making the appropriate changes that eventually supported student learning. Thus, it seems that the two approaches should simultaneously guide the design process: (a) a top down approach in which design is guided by well defined rationales in the form of design-principles or patterns, and (b) a

¹ Text in square brackets was added by authors to increase readability of excerpts from students’ comments.

bottom up approach in which solutions for emerging challenges are sought by successive trial and refinements.

Therefore, we claim that it is important to continue to formulate and refine existing design guidelines, and strengthen them by providing evidence of their impact in several contexts, as described in the “bird’s eye view” trajectory of this study, using the “features” unit of analysis. Examples from multiple contexts not only provide corroborations for design-principles, they also enable curriculum and course designers to see the variability of solutions and the limitations of design guidelines. By publishing the design-principles formulated in this study in the Design Principles Database, we hope to make them more accessible and usable for course instructors and designers. Moreover, the Design Principles Database enables further strengthening and refining of design principles by connecting these principles with new features. We encourage the readers of the Computer Human Behavior journal to join this collaborative endeavor, and contribute to the database from their research outcomes with regards to how their features support design principles.

It is important to note, though, that one limitation of the design-principles and design-patterns approach in general, and of the use of the database in this study in particular, is that design-principles and patterns tend to be somewhat difficult to communicate. Thus, it is a challenge to reuse design-principles in the sense that people can interpret them in different manners. In the current research, the authors were those who articulated the design-principles, as well as those who used them, creating a “privileged” situation in which communication issues were minimized.

That said, we would like to note an example in which two groups of researchers contributed their design-principles to the database and used each others’ principles to analyze their own designs, and to synthesize and elaborate the two groups’ design knowledge. In the Delineating and Evaluating Coherent Instructional Designs for Education (DECIDE) project, about 25 researchers from two large curriculum development centers used each other’s design principles (Kali, Linn, & Roseman, 2008). One of the project aims was to illustrate how similar rationales can be realized in very different manners, which have all been shown to be productive in supporting k-12 science learning. The learning materials developed by each center varied in many ways such as: short versus long term implementation; extensive versus sporadic use of technology; bottom-up versus top down choice of contents. However, by identifying the underlying assumptions and guiding principles of each center, negotiating the meaning of terms, specifying methods and procedures, and articulating common ground, the authors were able to leverage the two centers’ original design-principles and create a more explicit and communicative body of design knowledge. One of the outcomes of this process was refinement of the original design principles in the Design Principles Database. The DECIDE project illustrates how the communication issue, which is inherent to the use of design-principles can serve to promote further development in the field, provided that extensive negotiation takes place.

Finally, an important outcome of this study is that design guidelines can be strengthened by other design guidelines. The design-principles *engage learners in instruction of their peers and reuse artifacts as a resource for further learning* were supported in this study by employing the *provide knowledge representation and organization tools*, and the *employ multiple social-activity structures* design principles. When only the first two design-principles were employed, a pitfall inherent to the first design principle emerged: when students instruct each other, there is a danger that those who serve as instructors will benefit from the process more than their peer learners. This pitfall was faced by applying the two other design-principles, which eventually brought all learners to understand the three philosophical perspectives, even though they

specialized only in one. Earlier in this paper we claimed that a design pattern, according to Alexander’s (1979) design-patterns language is based on several constructs including *references to other patterns*. The outcomes of the current study, which illustrate how design guidelines can strengthen other design guidelines provide empirical evidence for the value of Alexander’s referencing to other design patterns. We recommend that frameworks that seek to abstract general guidelines for curriculum design, such as those suggested by Avgeriou et al., 2003; Brown, 1992; Herrington, 2006; Merrill, 2002; Mor & Winters, 2007; Quintana et al., 2004, and van den Akker, 1999, as well as the Design Principles Database, will enable referencing between design-principles and identifying clusters of design guidelines that strengthen each other, such as those identified in the current research. To accomplish this goal, researchers who explore design-principles and design-patterns need to join efforts and work together to synthesize findings from multiple case studies and research projects.

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