Demetriadis, S., & Pombortsis, A. (2007). e-Lectures for Flexible Learning: a Study on their Learning Efficiency. *Educational Technology & Society*, 10 (2), 147-157.

# e-Lectures for Flexible Learning: a Study on their Learning Efficiency

**Stavros Demetriadis and Andreas Pombortsis**
Department of Informatics
PO Box 888, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece
sdemetri@csd.auth.gr // apombo@csd.auth.gr

**ABSTRACT**

This study investigates the level of students' learning when using e-lectures to increase the flexibility of the learning experience. Two cohorts of students were presented with the same material in lecture format. The control group attended a traditional live lecture, while the treatment group was offered an e-lecture with the same content. Both groups were asked to work on specific review questions and encouraged to pose their own, as preparation for a knowledge-acquisition post-test. There were no significant differences in post-intervention measures regarding students' level of knowledge, but students in the e-lecture group (lacking immediate teacher-student communication) employed a strongly acquisitive mode of learning, thus undermining teacher-student dialogue later in classroom. The results of this study indicate that students may learn efficiently at the introductory level by using e-lecturing material and they are also satisfied by the flexibility of the experience. However, the adoption of e-lectures to support flexible learning should be explored in close relationship to models of course re-engineering that also foster instructional cohesiveness, by integrating the various learning events as interrelated nodes of a productive learning network.

**Keywords**

Digitized lectures, e-Lectures, Flexible learning, Blended learning, Media in education

## Introduction

Although lecturing is frequently criticized as a passive mode of instruction, strongly based on the idea of "knowledge to be transmitted," it still constitutes a major mode of teaching. It is "a defining element of most university courses" (Bell et al., 2001) "probably because it serves many functions not so well observed in the present research" (Fritze & Nordkvelle, 2003, p. 328). Nowadays, as a means of instruction, digital technology offers the possibility of easily transferring online the experience of the lecture. In most cases this comprises an audio or video feed of the lecture accompanied by a synchronized presentation of supporting material (lecture notes or electronic slides). An increasing number of institutions are reported to include such technology-delivered lectures in their distance-learning courses (Rui et al., 2004), and several studies explore the efficiency of using digital versions of lectures in various instructional scenarios (Spickard et al., 2002; Dev et al., 2000; Bell et al. 2001).

Digital lectures increase learning flexibility as students can easily access online material and reuse it as needed. Technological advances support the efficient development of digital lecturing material by making widely available both the necessary hardware (e.g. Joukov et al., 2003) and the appropriate software for easily viewing digital lectures (for example, the BMRC Lecture Browser).

In the context of this work, we use three different terms to classify the various formats of technology-delivered lectures.

- **Digital lecture**: any lecture delivered through digital technology, either online (synchronously) or on demand (asynchronously). In the former, students attend, from a distance, a live lecture transmitted to them through network services, while in the latter, a digitized version of the lecture is available via streaming technology or optical storage media (CD, DVD). Digital lectures can be captured either "in vivo" or "in vitro" (Wofford et al., 2001, see below).
- **Live digitized lecture (LDL)**: any digital learning resource that captures the experience of lecture-based instruction in the classroom, with students participating ("in vivo"). An LDL is simply a digital version of the live event (the instructor addresses the students who are physically present in the classroom).
- **e-Lecture**: any digital learning resource in lecture format, captured in the studio ("in vitro") with only the necessary technical personnel and with the purpose of engaging students in e-learning experiences. The lecturer addresses a virtual audience, that is, the students who will potentially attend the lecture at a later time. Distinguishing between LDLs and e-lectures is essentially a socio-cognitive issue rather than a technical issue. The reason for making the distinction will become evident later in this article.

We also make use of the "flexible learning" and "blended learning" notions:

- **Flexible learning**: Learners are offered a variety of options for personalizing the learning experience based on their specific needs and preferences. To increase flexibility, therefore, means essentially to overcome obstacles emerging from the rigidity of traditional forms of education by enabling learners to select what is best for them with respect to key dimensions of learning (Collis & Moonen, 2001).
- **Blended learning**: Activities that combine classroom learning with web-based instruction (Whitelock & Jelfs, 2003). It is not, however, the simple aggregate of face-to-face and technology-enhanced learning. Instead, blended learning emerges from the functional integration of the two instructional modes, which in practice means that "blended learning courses have the potential to offer the convenience and flexibility of online courses yet still maintain the interactivity and face-to-face contact offered through traditional courses" (Jones et al., 2003, p. 43).

Along with other researchers, we maintain that the idea of transforming traditional lectures to digital format has some compelling advantages with regard to cost and flexibility. Instructors have the option of digitizing their classroom activities and making them readily available to students beyond place and time constraints, thus increasing flexibility of learning. Furthermore, once produced, digital lectures may always be available on demand, increasing the cost/performance ratio of e-learning services.

However, we argue that technology-delivered lectures should be made available to students only through a cautious exploration of applicable pedagogical scenarios on how to engage students in fruitful learning interactions supported by this specific technology. Following this rationale, we suggest that an interesting option in tapping the potential of audiovisual digital resources is to develop thematically focused, short e-lectures. These e-lectures should concisely present well-seasoned topics that need not to be regularly updated and may be offered to students as introductory material to engage them in blended-learning activities. Instructors can develop this kind of material using simple studio facilities and with ample time to work on improving their lecturing style. In our study we investigate the issue of students' learning when using such e-lecture material for preparation in a blended learning design, addressing two specific questions:

- Are e-lectures as efficient as traditional lectures for students' learning?
- What is the level of students' satisfaction and the attitudes they develop regarding the use of e-lectures?

## Literature Review

Comparative studies of live and technology-delivered lectures appeared in the epoch of early TV and video tapes, long before digital technology was widely available. Schramm, in summarizing the results of more than 400 studies comparing televised and classroom lectures, concludes confidently that students learn from technology-supported environments quickly and efficiently (Schramm, 1962, cited in Saba, 2000). Ellis & Mathis (1985) report twelve studies from as early as 1957 that fail to identify any significant difference between students who attend live lectures and those who attend televised lectures. The authors claim that "students can learn introductory college material as well from video-taped lectures as from lectures taught in-person." (Ellis & Mathis, 1985, p. 171).

More recently, Wofford et al. (2001) argue that moving the traditional clinical lecture to the computer,should be an appropriate strategy for efficiently dealing with cost-containment pressures in education. The authors review eight studies concerning medical education. These studies compare the live lecture not specifically to the digital lecture but to various other design interventions based on computer technology (some of them being multimedia computer presentations). Six of these studies show no difference in effectiveness, while two of them favor the computer-based strategy. The authors conclude that digital lectures should be no less effective than traditional lectures.

Several other studies also focus on the use of digital lectures in medical education, highlighting the need for reusable and flexibly accessible learning resources in this specific field. Spickard et al. (2002) examine the effect of using e-lectures to deliver medical curricular content to students who participate in an outpatient clerkship. The control group attended a traditional live lecture, while the treatment group was offered the possibility of viewing an Internet-based PowerPoint presentation synchronized with an audio feed (lecturer's narration). No differences were found in the different groups' learning, and the authors argue that an online lecture is a feasible, efficient, and effective method for instruction. Moreover, they encourage the direct comparison between digital and live lecture format, emphasizing that such studies seem to be fairly limited in number.

Dev et al. (2000) at the Stanford University School of Medicine employed the digital-lecture-as-study-supplement approach and made available to students a streaming video capture of the classroom event. In analyzing usage patterns, researchers observed that students used the video material for review (particularly before course examinations) and not to replace classroom attendance. Although some faculty reportedly complained that video lectures contributed to poor attendance and gave students confidence to skip classes, the authors insist that this is not the case.

However, in a similar study regarding a first-year university computer-studies course, the effect of students' skipping classes was rather intense (Bell et al., 2001). Moreover, students did not access the live digitized lectures (at least to the degree expected) although they intended to do so (according to their statements). The authors conclude that too much flexibility can have a negative affect on learning.

Overall, studies in the literature indicate that:

- Digital lectures may exhibit a variety of features: be available online (synchronously) or on demand (asynchronously), captured in vivo or in vitro, comprise various representational codes and modalities (audio vs. video feed).
- Direct comparisons between live lectures and those that are technology delivered (televised or computerized) result generally in insignificant differences in learning outcomes.
- Incorporating digitized classroom lectures as a supplement to university courses garnered mixed results and may have increased the risk of poor attendance.

Despite the fact that the overall picture emerging from these studies is rather encouraging, we argue that the integration of digital lectures in the curriculum should not be considered a simple and straightforward enterprise without critical considerations. First, although one may conceptualize all types of lectures (live, LDLs, e-lectures) as being structurally isomorphic, research indicates that the context of delivery strongly affects the format of the lecture, inducing changes in the way that the lecturer makes use of various social and cognitive aspects (such as humour, gestures, and instructional examples) (Fritze & Nordkvelle, 2003). In lectures captured in vitro and addressing a virtual audience (such as video-lectures and e-lectures), the lecturer adopts a different social role, more as a representative of the scientific community rather than as an educator. Presumably such (and possibly other) variations may in turn have an effect on the way that lectures of various formats can be optimally integrated in the learning process. This, we suggest, is an important reason for distinguishing between lectures based not simply on the delivery medium but also on their different socio-cognitive underpinnings.

Second, capturing a live lecture is still of considerable cost due to the necessary infrastructure and experienced technical staff (Rui et al., 2004), even though the development of reusable digital material is generally expected to reduce the overall cost of delivering online learning (Wofford et al., 2001). Third, producing an LDL can be a time-consuming task. Dev et al. (2000) point out that preparing the digital lecture material may well demand three times as much time as the length of the live lecture. (Of course, this ratio varies depending on the technology and the post-production processing of the video feed). Hence, updating a course to include lengthy digitized lectures, may become a time-consuming and costly enterprise.

Finally, the experience reported by Bell et al. (2001) shows clearly that the availability of digitized lectures as an alternative, involves the risk of discouraging students from attending the live event and minimizing teacher-student interaction. This is a strong indication that flexibility should not become the sole objective when re-engineering a course. We discuss this point more comprehensively in the next section, in our effort to conceptualize how to build constructive boundaries for flexibility-generated detrimental effects in learning.

## Establishing cohesiveness

If being flexible means primarily to provide options for learners, then being cohesive refers to applying an adequate pedagogical framework that adds instructional value to learners' options by projecting these options as interlinked nodes in a network of learning events. In such a network, the degree of cohesiveness (or interconnectedness) between any two events is related to the importance assigned by a learner to event A as a prerequisite for B. Considering A a required step before proceeding to B increases the perceived cohesiveness of the events and enhances the structure of the whole learning experience, albeit lowering flexibility (event B may not be available or the learner may not wish to participate in B if A is not first completed). Cohesiveness reflects the effect of both externally applied constraints (relative to curriculum or the instructional design) and the learners' internal beliefs (such as the students' perceived instructional value of an activity in relation to course objectives). It also offers a measure of students' commitment to participating in a specific learning event (or a sequence of events).

Increasing flexibility by integrating digital lectures may strongly affect the cohesiveness between various learning events, since using a different medium can alter students' priorities for participating in certain events. When offering the digitized lectures simply as study supplement, it is possible that students will interpret this as a decrease in cohesiveness between the live lecture and course assessment events and may skip classes because they are confident that an adequate level of performance can be achieved by another mode of participation (i.e., viewing the digital lectures). This, we believe, is more likely to happen if the opportunity for constructive teacher-student interaction is missed by the instructor in the live event.

Fostering cohesiveness in this case would mean establishing conditions for ensuring that learners are engaged in an adequate level of interaction and information processing, independent of their preferred option for learning. For example, the cohesiveness between the live lecture and students' successful performance can be enhanced by increasing teacher-student dialogue during the lecture. Likewise, the degree of cohesiveness in a learning design that includes digital lectures can be increased by introducing an online post-lecture activity suitable for the students who missed the live event and viewed the digital version instead.

Instructional cohesiveness, therefore, embodies the simple but essential idea that any learning option should be embedded in a framework of learning activities that guarantee conditions of efficient learning.

## Integrating e-lectures in blended learning activities

In line with our view to productively combine flexibility and cohesiveness, we argue that a promising model towards this direction is the "before-during-after" model for course re-engineering (Collis & Moonen, 2001). The model suggests that students are engaged in some kind of preparatory learning activity (the "before" event) prior to their participation in a focal activity (the "during" event), to be followed up by some appropriate concluding activity (the "after" event). A popular implementation of the model includes conducting the focal event face to face (F2F) and dividing the rest of the instructional time between online "before" and "after" activities. This establishes cohesiveness through the "before-during-after" linking of the events and supports flexibility by making a significant part of the learning experience available online.

Following this perspective, our study explores the scenario of an instructor who wishes to deliver the "before" event online, having her students informed on the basics of the topic prior to the focal event in the classroom. She anticipates that in this way a certain part of F2F lecturing time (usually devoted to presenting introductory issues) can be freed and invested in more productive learning activities. She knows that a well-organized multimedia presentation can be more appealing to students and also instructionally more effective when compared to a mono-media presentation. Keeping in mind that short e-lectures are more likely to maintain students' attention (Campbell et al., 2004), she opts for shooting some "mini" e-lectures to introduce the course major topics. She then asks her students to view an e-lecture in order to prepare themselves for an elaboration session to be held in classroom.

However, the instructor believes that e-lectures should not be considered equivalent to traditional live lectures because of the several interrelated socio-cognitive factors that affect learning. In a live lecture the presence of an authoritative and facilitating persona (instructor) may motivate the students to attend and cognitively process the presented information. On the contrary, when viewing an e-lecture, there is always the risk that learners may miss some critical point or not process the information effectively if they lack the stimulation of the live event or they are distracted by accidental environmental disturbances (even though the e-lecture can be viewed several times). Furthermore, a live lecture provides (at least in principle) an opportunity for uninterrupted and constructive teacher-student dialogue, thus being a considerably more dialogue-oriented learning activity compared to the rather content-oriented experiences offered by technology-delivered lectures (Fritze & Nordkvelle, 2003). Teacher-student interaction is expected to improve students' understanding in a live event and should be somehow compensated for when using e-lectures.

Within this context of re-engineering considerations, the instructor is interested to know (a) whether her students will be equally well-prepared when using e-lectures (in comparison to traditional classroom lectures), and (b) if this will be a satisfactory experience for the students.

## Method

### Participants and context

To answer the above questions we conducted a completely randomized one factor–two treatment study. Fifty-three (53) students enrolled in the Multimedia Systems course in the $6^{th}$ semester of their studies volunteered to participate. This course is a required course, and the topic of instruction (JPEG-compression scheme) is one of the most important covered (along with other image-, sound-, and video-compression schemes). In return for volunteering, students were offered a bonus grade for the course, provided that they obtained at least a passing grade in the post-test of the study.

Typically, the instruction of this topic involves a lecture that presents to students a model of the compression scheme. Emphasis is on raising students' understanding of how the original digital image signal is compressed through a series of appropriate transformations. No deeper mathematical analysis is involved at this level but rather an introductory qualitative approach is followed. This means that the learning objectives are relative to the first two cognitive processes in Bloom's revised taxonomy (Anderson et al., 2001), namely remembering and understanding factual and conceptual knowledge. Later on the course shifts focus to higher levels as well (application and evaluation) but this is outside the scope of this study.

Students were completely randomly allocated to either an experimental or a control group, stratified by gender (*experimental*: 26 students, 9 female; *control*: 27 students, 10 female). The control group attended a typical live lecture that provided ample opportunity for teacher-student interaction (reviewing the lecture material through discussion). The same content was presented to the experimental group in e-lecture format (video feed of the lecturer synchronized with PowerPoint slides). To compensate for the lack of immediate teacher-student communication, students in this group later met the instructor in the classroom for a face-to-face discussion similar to one that occurs in the live lecture group.

Our study evaluated students' learning immediately after these connected learning events (viewing the lecture and interacting with the instructor). The independent variable was the mode of students' preparation (live, interactive lecture vs. e-lecture combined with classroom meeting), while the dependent variables were students' learning outcomes as measured by a post-test questionnaire. Our null hypothesis ($H_0$) was that students who study by viewing an e-lecture and participating in a F2F review meeting perform equally well in a test of basic understanding as those who attend a live, interactive lecture, provided that they are appropriately motivated and the level of instruction is introductory.

### Control Condition

The study was organized in four phases:

1. *Pre-test*: To verify that students were novices and stratification was successful, students were asked to complete a pre-test knowledge instrument. This was a six- item questionnaire comprising short-answer introductory domain questions.
2. *Study*: Students in the control group attended a traditional lecture in a classroom. During the lecture, PowerPoint slides were used to present textual information, graphics, and a few animations.
3. *Review*: Immediately after the lecture, students were given six review questions to answer. They were also asked to freely pose their own questions and discuss them with the instructor. After discussing and providing satisfactory answers to all of these questions, students took the post-test.
4. *Post-test*: To record students' level of learning a five-item questionnaire was used. This post-test instrument comprised open-ended questions asking students to provide a well-supported answer in a few sentences (see Appendix). No other instrument was given to the control group.

### Treatment condition

The study of the e-lecture group was also organized in four phases:

1. *Pre-test*: The same six-item pre-test questionnaire was administered to this group.
2. *Study*: One week before the scheduled classroom meeting, students were instructed to view the e-lecture at home, as many times as they wished, in order to get well prepared for their post-test examination. They were given the same six review questions as the control group and they were asked to have their answers prepared (as well as any further questions they wanted to pose) for the review F2F meeting. The e-lectures were

available on a web server for downloading, but were also given to students on a CD to avoid dissatisfaction because of possible technical problems (slow downloading due to low bandwidth connections, for example). Students were presented with two e-lectures: one on the topic of digitization and another on the topic of the JPEG-compression scheme. They were aware that the final test was only on the JPEG topic, but we decided to offer two e-lectures to encourage students to become familiar with this presentation format.

3. *Review*: Students met the instructor in classroom and presented their answers to the six review questions. They also posed their own questions to the instructor. After complete answers were given, they took the post-test.
4. *Post-test*: The same post-test instrument (six open-ended questions) was given to this group. Furthermore, we asked students to complete a seven-item Likert-scale questionnaire to record their attitudes regarding the e-lecture experience. Along with that we asked students to explicitly report what they liked most and what they liked least about the experience.

## Results

### Pre-test

The pre-test confirmed that students in both groups were novices at the same level, with regard to their previous domain knowledge (control group: *n*=27, M=1.4, SD=1.48, maximum possible score was 18; experimental group: n=26, M=1.3, SD=1.16, t(51)=-.374, p=.71, Cronbach's a=.349).

### Study

The live lecture was about 14 minutes, while the e-lecture was 8.37 minutes. This difference was due to the slower pace of presentation in the live lecture. However, the students in the experimental group reported viewing the e-lecture about 3 times (M=2.94, SD=1.20), thus resulting in a total e-lecture viewing time of 24.6 minutes.

The review phase for the live-lecture group lasted about 27 minutes (answering both review and the students' own questions). For the experimental group the respective time interval was about 11 minutes. Therefore, the duration of the whole activity for the live-lecture group was 41 minutes (14+27) while for the treatment group it was approximately 35.6 minutes (24.6+11).

The answers that students gave to the review questions were quite satisfactory for both groups (no formal record available). Students in the e-lecture group, however, posed significantly fewer questions (three questions) than the live-lecture group (nine questions). None of these three questions was similar to those posed by the live-lecture group. A subjective instructor's impression is that students in live-lecture group were significantly more willing to pose questions and further discuss issues on the presented topic before going on to take the final test.

### Post-test

Immediately after the review phase, students in both groups were given the post-test questionnaire and were asked to complete it within 20 minutes. This proved to be enough time for the students in both groups.

*Table 1*. Results of t-test between the two groups

| | Mean (SD) | t-test | Significance | Equality of variance | Normality | Reliability |
|---|---|---|---|---|---|---|
| Control group (live lecture) (n=27) | 12.65 (2.74) | Two-tailed | No<br>t(51)=.644 p=.522 | Yes<br>F=2.024 p=.161 | Yes<br>Control (n=27) Z=1.116, p=.166<br>Exp. (n=26) Z=.884, p=.416 | Moderate<br>Cronbach's a=.636 |
| Experimental group (e-lecture) (n=26) | 13.08 (2.04) | | | | | |

Two independent evaluators (experienced in assessing students' previous work in the same course) assessed the students' answers and assigned grades according to the following scale: 3=accepted (correct answer, well presented and explained); 2=minor revisions (acceptable answer, correct path of reasoning in general, but some elements missing); 1=major revisions (non-acceptable answer and incorrect path of reasoning in general, but some elements in students' answers, seen in isolation, were acceptable); 0=rejected (completely wrong answer or no answer at all).

The results of the post-test are presented in Table 1. Significant differences between the two groups were assessed using an independent two-tailed Student's t-test. The a-level was set to 5%.

**Students' attitude questionnaire**

Students' attitudes towards learning from the e-lecture are presented in Table 2. A five-step Likert scale was used in this instrument (1=STRONGLY DISAGREE, 2=DISAGREE, 3=UNDECIDED, 4=AGREE, 5=COMPLETELY AGREE). Students' likes and dislikes (major positive and negative aspects of the experience) are presented in Tables 3 and 4 (free-text answers ranked by the number of occurrences).

*Table 2*. Students' answers to attitude questionnaire regarding the e-lecture experience (n=26).

| Item No. | STATEMENT | Mean |
|---|---|---|
| 1 | I consider the digitized lecture that I viewed as a positive learning experience | 4.94<br>STRONGLY AGREE |
| 2 | Technically, the quality of the e-lecture was completely satisfactory | 4.35<br>AGREE |
| 3 | I think that learning from e-lectures is in no aspect inferior compared to learning from a live lecture, considering the presentation and transmission of information | 3.42<br>UNDECIDED |
| 4 | I think it is important to develop online e-lecture libraries for a course so that I can view an e-lecture any time I wish during the semester | 4.88<br>STRONGLY AGREE |
| 5 | After viewing the e-lecture I believe it is necessary to, somehow, ask questions to the instructor (for example, meeting him/her later in the classroom) | 4.82<br>STRONGLY AGREE |
| 6 | I think that viewing an e-lecture at home as many times as I wish gives me the opportunity to better reflect on the content of the lecture | 4.88<br>STRONGLY AGREE |
| 7 | I believe that combining e-lectures and classroom meetings for discussion (or other review and elaboration activities) can be a better learning experience compared to the integrated traditional lecture in the classroom | 4.49<br>AGREE |

*Table 3*. Positive aspects of the e-lecture experience

| Item No. | Students Reporting (n=26) | FREQ. | This aspect relates to…[1] | | |
|---|---|---|---|---|---|
| | | | F | C | M |
| 1 | Watching the e-lecture as many times one wishes results to better learning | 15 | x | x | |
| 2 | Ample time to get prepared and pose better stated questions | 3 | x | x | |
| 3 | Better study conditions at home (feel more comfortable, better able to concentrate, do not get tired as in classroom, follow one's own pace) | 3 | x | x | |
| 4 | With digitized lectures available one does not miss the lecturing event | 2 | x | | |
| 5 | Able to review the e-lecture material without bothering the teacher | 1 | x | | |
| 6 | Feel motivated by the use of audiovisual technology | 1 | | | x |
| 7 | e-Lecture enables participation and so it is more interesting | 1 | x | | x |
| | TOTAL | 26 | 25 | 21 | 2 |

[1] F=Flexibility, C=Cognition, M=Motivation

*Table 4*. Negative aspects of the e-lecture experience

| Item No. | Students Reporting (n=26) | FREQ. | This aspect relates to… | | |
|---|---|---|---|---|---|
| | | | F | C | M |
| 1 | Lack of immediate discussion while viewing the e-lecture (students may forget questions they wish to ask, not bother to ask them at all or misunderstand some point in e-lecture) | 20 | | x | |
| 2 | Excessive comfort at home and availability of the e-lecture may promote procrastination | 2 | x | x | |
| 3 | More pleasant to attend a live lecture than a digitized one | 1 | | | x |
| 4 | When e-lectures become an everyday routine they may lose their appeal | 1 | | | x |

| | | | | | |
|---|---|---|---|---|---|
| 5 | Better to have both live lectures and e-lectures (as supporting material) | 1 | x | x | |
| 6 | I cannot find any negatives. Personally, I like the idea and I would like it to be applied. | 1 | | | |
| | TOTAL | 26 | 3 | 23 | 2 |

## Discussion

### Study design

In this study we have argued that while striving for flexibility one should also establish cohesiveness of the various learning events. In implementing this approach we explored the efficiency of short and thematically focused e-lectures as introductory learning material within the context of specific blended learning activities. Regarding previous studies, our design is different in some critical aspects:

- Unlike Spickard et al. (2002), we included a live teacher-student dialogue component both for control and treatment groups. This feature adds ecological validity to our approach since most instructional designs are expected to include such teacher-student interaction to facilitate learning.
- Unlike Dev et al. (2000) and Bell et al. (2001), we offered the e-lecture as study material and not as an optional review resource. Our research therefore provides evidence about the actual potential of e-lectures to support learning and not simply about the patterns of their possible usage by students.

Furthermore, it is worth emphasizing that although this study generally follows a formal experimentation design, aspects of a more naturalistic design are also implemented (such as the fact that students in the e-lecture group were allowed to view the e-lecture many times, while students in control group attended the live lecture only once). We do not consider this as a design flaw. Contrary, we argue that research should aim at simulating authentic situations as much as possible, thus providing evidence on the efficiency of instructional designs in real-world conditions.

### Interpretation of results

Quantitative data indicate that there is no significant difference in the learning outcomes of the two groups as measured by a post-test questionnaire, similar to questionnairs that an instructor would use to determine the students' level of understanding. Our null hypothesis, therefore, holds true, and we conclude that students may learn equally well either from a live-lecture or an e-lecture experience, provided that (a) they are motivated (for example, by grade) and (b) instruction is at the introductory level. However, in generalizing this conclusion one should keep in mind that the students who participated, being computer science students, were keen to use computers for working and learning.

Qualitative data, on the other hand, reveal a lower level of teacher-student dialogue during the F2F part of the blended learning activity. Possible reasons for that may include:

- Students would like to pose questions while viewing the e-lecture but they did not bother to take any notes (although they were instructed to do so) and it was difficult to recall their questions when they returned to the classroom .
- Students opted for reviewing the digital material as many times as they felt necessary and did not really expect much support from the delayed teacher-student dialogue. When in the classroom they felt that no further discussion was needed for getting adequately prepared for their introductory-level test.
- The live lecture experience encouraged teacher-student dialogue as a means for attaining deeper understanding of the presented material.

Although no other data has been recorded to help us more accurately model the relative impact of the aforementioned causes on students' observed behavior, we suggest that the combined effect of the latter two should be considered responsible. Students certainly had a concrete motive to attain a firm understanding of the lecture content and get a good grade in their test. Those in the live lecture, not being able to review parts of the lecture, posed questions and discussed issues with the instructor. The role of lecturer primarily as an educator created a socio-cognitive environment that encouraged students to adopt a more participatory and dialogue-oriented attitude in order to ensure an adequate level of understanding. Those in the e-lecture group, however, lacking any immediate communication with the instructor who acted principally as a presenting scientist, developed a positive attitude toward memorizing and understanding information by reviewing the e-lecture several times. As other studies also emphasize (for example, Spickard et al., 2002), it is possible that group discussion was considered (and eventually proved to be) less needed to achieve students' learning goals. Overall, it seems that (i) the possibility for multiple reviews of the e-lecture, (ii) the perceived role of the instructor, (iii) the spatiotemporal separation between study and live interaction phases, and (iv) the less demanding level of introductory instruction encouraged students in the e-lecture group to adopt a strongly acquisitive mode of learning in their effort to get prepared for the post-test as adequately as possible.

These considerations offer support to the tentative statement that the way that learning activities are allotted to the various media has an effect on students' learning, since any particular media feature may encourage and amplify certain learning attitudes, depending on students' beliefs about its supportive role towards achieving the learning objectives. If this is so, then fostering only cohesiveness of learning design should not be considered adequate. Care should also be taken to efficiently match the attributes of the media used for delivery to the sociocognitive conditions favorable to any specific learning activity. We refer to this notion as "media suitability," and we argue that this and cohesiveness should be considered two important design pillars of blended learning activities.

Students' answers to the attitude questionnaires (Tables 2, 3, and 4) indicate that although students managed to deal successfully with the learning situation, they nevertheless think of the delayed teacher-student communication as a negative aspect of the experience (Table 4, item 1). Their dissatisfaction is also evident in the low rating of item 3 in Table 2. This is an indication in favor of providing technology-supported communication to students when using e-lectures. We think that ideally students should be supported by some asynchronous service (for example, a forum), since using synchronous services would further reduce flexibility.

Some other issues that students report as shortcomings of their e-lecture experience have already been reported in the literature, such as the risk of procrastination due to excessive flexibility (Bell et al., 2001) and a possible lack of motivation when the use of such material becomes an everyday routine (Clark & Craig, 1992) (Table 4, items 2 & 4).

However, students do acknowledge that using e-lectures has some important advantages considering the flexibility of delivery and related learning benefits (see Table 3, items 1–3 and also Table 2, items 4 & 6). In general, students seem to be pleased by the whole experience (Table 2, item 1) and welcome the availability of e-lectures as learning material (Table 2, item 4), but also emphasize the importance of teacher-student communication (Table 2, item 5), highlighting the need for improvement in this specific instructional design to enable students to fully benefit from e-lectures.

### Limitations & future research

In this study, we focused on instruction at an introductory level, encouraging however a strongly acquisitive, albeit sufficient, learning attitude. Future experimentation should explore alternative designs aiming at higher levels of learning as well (e.g. analyze, evaluate, and create). A focal question here is if and how a contribution-oriented instructional design can take advantage of e-lecturing material and establish cohesiveness among online and onsite activities. An interesting possibility would be to have the e-lecturing instructor support the students' individual or group work by modeling, for example, the construction of a deliverable. Online communication services can be used for supporting extensive teacher-student interaction, and the coaching instructor can later bring into the classroom the major issues emerging during the online activities, thus developing a bridge between the online and the F2F components of the learning experience.

We have also argued that establishing cohesiveness and media suitability should be considered important steps in the blended-learning design process. Research is needed to elaborate on these issues and better model the process. For example, it is interesting to investigate whether the e-lecture experience can become more dialogue-oriented if students are offered simultaneously the opportunity of online communication with the instructor, instead of postponing it to take place in classroom. A possible positive answer would offer further support to the notion of media suitability, indicating that the way of distributing activities over media affects the learning attitudes that students develop when engaged in the activities.

Finally, an important limitation of our study is the students' background (they were positively biased towards using digital technology as a means for learning) and the fact that their learning styles have not been taken into account in any way. It is questionable whether the same results can be obtained with students of a different background. Moreover, since e-lectures and live lectures have different sociocognitive underpinnings they possibly do not equally fit students with different learning styles. Research can provide evidence on how students' different backgrounds and learning styles may interact with the mode of presentation.

## Conclusions

This study provides evidence that e-lectures can be safely used as students' introductory learning material to increase flexibility of learning, but only within a pedagogically limited perspective of learning as knowledge acquisition (as opposed to construction). It also highlights the fact that the availability of the e-lecture in combination with the spatiotemporal separation between study and review activities results in a lower level of teacher-student dialogue, which nevertheless did not influence the students' post-test performance.

Based on our experience, we argue that the adoption of e-lectures should be explored in close relationship to promising models of course/session re-engineering that (a) foster instructional cohesiveness by integrating the various learners' options as interconnected nodes of a productive learning network, and (b) efficiently match the attributes of the used media to the sociocognitive conditions favorable to any specific learning activity.

## Acknowledgments

The authors wish to thank Athanasios Karoulis, Konstantinos Karoulis, and Asterios Hatziharistos for their valuable help in various phases of this study.

## References

Anderson L. W., Krathwohl D. R., Airasian P. W., Cruikshank K. A., Mayer P. E., Pintrich P. R., Raths J., & Wittrock M. C. (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's taxonomy of educational objectives,* New York: Longman.

Bell, T., Cockburn, A., McKenzie, B., & Vargo, J. (2001). Digital Lectures: If you make them, will students use them? Constraints on effective delivery of flexible learning systems. *Interactive multimedia electronic journal of computer-enhanced learning*, retrieved May 10, 2007, from http://imej.wfu.edu/articles/ 2001/2/ 06/index.asp.

Campbell, G. M., Garforth, A. A., & Bishop, A. (2004). Engaging first-year chemical engineering students with video-based course material. *Proceedings of the networked learning conference*, retrieved May 15, 2007, from http://www.shef.ac.uk/nlc2004/ Proceedings/Contents.htm.

Clark, R. & Craig, T. (1992). Research and theory on multi-media learning effects. In M. Giardina (Ed.), *Interactive multimedia learning environments: Human factors and technical considerations on design issues,* Berlin: Springer-Verlag, 19–30.

Collis, B & Moonen J. (2001). *Flexible learning in a digital world,* Oxon: Routledge Falmer.

Dev, P., Rindfleisch, T. C., Kush, S. J., & Stringer, J. R. (2000). An analysis of technology usage for streaming digital video in support of a preclinical curriculum. *Proceedings of the AMIA Symposium*, 180–184.

Ellis, L., & Mathis, D. (1985). College students learning from televised versus conventional classroom lectures: a controlled experiment. *Higher Education,* 14, 165–173.

Fritze, Y., & Nordkvelle, Y. T. (2003). Comparing lectures: Effects of the technological context of the studio. *Education and Information Technologies,* 8 (4), 327–343.

Jones, V., Jo, J. H., & Cranitch, G. (2003). A blended e-learning solution for the delivery of tertiary education. In António Palma dos Reis and Pedro Isaías (Eds.), *Proceedings of IADIS International Conference e-Society,* Lisbon, Portugal, 42–47.

Joukov, N., Fauster,. M., & Chiueh, T. (2003). Design, implementation, and evaluation of a digital lectern system. *Proceedings of International Conference on Web-based Learning* (ICWL '03), 241–252.

Rui, Y., Gupta, A., Grudin, J., & He L. (2004). Automating lecture capture and broadcast: technology and videography. *Multimedia Systems,* 10, 3–15.

Saba, F. (2000). Research in distance education: A status report. *International review of research in open and distance learning,* 1(1), retrieved May 10, 2007, from http://www.irrodl.org/index.php/irrodl/ article/view/4/24.

Schramm, W. (1962). What we know about learning from instructional television. In W. Schramm (Ed.), *Educational television: The next ten years.* Stanford CA: The Institute for Communication Research, Stanford University, 66–67.

Spickard, A. III, Alrajeh, N., Cordray, D., & Gigante, J. (2002). Learning about screening using an online or live lecture: does it matter? *Journal of general internal medicine,* 17, 540–545.

Whitelock, D. & Jelfs, A. (2003). Editorial: Journal of educational media special issue on blended learning, *Journal of Educational Media,* 28 (2–3), 99–100.

Wofford, M. M., Spickard, A. W. III, & Wofford, J. L. (2001). The computer-based lecture. *Journal of general internal medicine,* 16, 464–467.

## Appendix

**Post-test questionnaire**

1. Do you agree with the opinion that lossy image compression happens when the Discrete Cosine Transformation (DCT) is applied on the original digital image signal? Yes or no and why?
2. Do you think that it is possible to have a compression scheme that applies first an entropy compression algorithm (like RLE) on the digital data to be followed by DC transformation? Yes or no and why?
3. In your opinion, do the higher or the lower values of the DCT coefficients indicate higher compression of the image? Why?
4. Describe a technique to vary the compression level when applying the JPEG scheme (what should be varied in order to achieve lower or higher compression?)
5. If the DC transformation of a digital image results in high values for the coefficients of the higher order frequencies, what does this imply for the visual information of the image file?