Learning Styles as a Design Parameter for Asynchronous Web-based Learning Modules

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Abstract

Asynchronous web-based resources offer the potential for an individualized learning process. Each learner may tailor the experience with regard to depth of content, order of presentation, and repetition of material. A web-based resource makes multimedia content easily accessed and updated, and also provides the flexibility for user tailoring. To exploit this flexibility in the learning process, the resource developer must anticipate and accommodate the needs of learners while efficiently satisfying the educational objectives of the instructor. Learning styles analysis provide a guide for evaluating the resource as an effective learning environment for students with different learning styles.

A learning-styles study on the effectiveness of tutorial modules is described within the context of an engineering subject. Sequential and global learner characteristics were considered as a design parameter. Similar versions of several resource modules were designed to meet the expected desires of sequential and global users within the context of a graduate/senior-elective electrical engineering course. The tutorials provided an introduction to the basic concepts, terminology, and mathematics for the class. The learning style classifications of students were correlated to their success and satisfaction with specific versions of the tutorials. In particular, four assessment instruments were used: the Felder-Soloman Learning Styles Inventory, short content quizzes to assess learning after specific module lessons, a content examination at the end of the introductory session, and a student satisfaction survey taken at the end of the session. A match between students' preferred learning styles and the associated version of the tutorial modules produced a minor improvement in student learning and satisfaction.

I. Introduction

In the information age, engineering students face an increasing amount of knowledge that must be mastered for success and professional growth, yet pressure exists to reduce the curriculum requirements in many engineering programs to encourage student enrollment. Also, working engineers have a greater need to acquire knowledge throughout their busy careers. Therefore, improvements in the effectiveness of the engineering learning processes are important issues. Better understanding of the learning process and application of learning styles to class design can create opportunities for such improvements. Learning styles reflect that different individuals have preferred ways to learn. Because of its promise to improve learning effectiveness, it was ranked by James Stice as one of the eight key educational innovations in the last thirty years.[1]

Asynchronous web-based learning modules are intended for self-paced use. These modules can provide an opportunity to apply pedagogical concepts to individualized student learning. In particular, these modules can be specifically designed to appeal to students with specific learning styles. This tailoring is an advantage to instructors that have preferred teaching styles and that have difficulty modifying their methods to facilitate the learning for students with differing or opposing learning styles. In addition, these asynchronous learning modules can provide a rich learning environment when developed with due deliberation and planning.

The purpose of this study was to test whether learning environments designed to favor specific learning styles enhance learning for students with those learning styles, and whether it impacts their satisfaction with the experience.[2] Tutorial resource modules were developed and tested in a graduate/senior-level elective engineering electrical engineering course. Versions of the modules were designed for sequential and global learners. Sequential users prefer to process information linearly, and global users prefer to obtain information holistically or in the context of the "big-picture." Four learning instruments were used to assess student learning style, content learning, and student satisfaction. Subtle variations in the modules were correlated to minor improvement in student learning and satisfaction.

II. Learning Styles and Learning Modules

The Learning Styles concept is an educational tool that has been widely used in disciplines outside of engineering education. Della-Dora and Blanchard (1979) define learning style as a "personally preferred way of dealing with information and experiences that crosses content areas". During the last few decades, considerable research has been done in the area of educational psychology, dealing with learning styles. This work includes: Harry Reinert's ELSIE (Edmonds Learning Style Identification Exercise),[3] Keefe's research studies conducted at the secondary school level,[4] the Lloyd J. Campbell's Learning Style Profile (LSP) (1990) applied with group teaching methods in the sixth grade classroom,[5] Hugh F. Keedy's (1978) study that examined the use of cognitive learning and teaching style,[6] Witkin's (1977) series of experiments on vertical perception,[7] and David A. Kolb's (1976) learning cycle with improved learning performance when the four processes (experience, observation, conceptualization and experimentation) are integrated. [8]

However, few studies document the impact of learning style upon student learning in the engineering environment. One research study done in engineering education at the collegiate level found some success with learning style application (Sharp, 1997)[9]. In 1979 James E. Stice[10] used Kolb's Learning Cycle to improve student learning, and found that if the teacher's learning style is similar to that of the students, then learning is enhanced. Other studies in non-engineering academic areas support the importance of learning styles. Becker and Dwyer[11] found that accounting students who are visual learners perceived groupware tools to be more effective and beneficial than did verbal learners. Loomis[12] found that the learning and study styles of journalism students played a crucial role in their success in a research methods class.

Several constructs and tools have been developed to implement learning styles concepts and assess the learning styles of individuals. These are called Learning Styles Inventories (LSI). There are a number of these tools. Joseph Hill's Cognitive Style Interest Inventory,[3] a broad-base instrument, examines the interacting influences of communicative symbols, sensory experiences, and programmatic cues. Anthony Papliea's Learning Modalities and Individual Difference Inventories, provides the students' self-assessment of their cognitive preferences as well as the teachers' observations. David E. Hunt's Paragraph Completion Method probes into the learner's conceptual maturity level. A. A. Canfield[13] designed multidimensional inventories to assess both the students' LS and teacher's instructional styles. The Dunn, Dunn, and Price Learning Style Inventory is designed to analyze the influences of environmental, emotional, sociological, and physical stimuli in determining individual learning patterns.[3] The Learning and Study Strategies Inventory (LASSI)[12] was developed by the University of Texas at Austin and consists of ten scales that measure different learning components. Kolb's Learning Style Inventory was developed by David Kolb, et al. in the 1970s[8] then revised in 1985.[14] It is the most notable and frequently used LSI at this time. However, none of these constructs were developed with engineers in mind.

Focusing on engineers, Richard M. Felder and Barbara Solomon of North Carolina State University developed the Felder-Solomon Learning Style Model. The Solomon and Felder's Index of Learning Styles is a 44-question survey that can generate a quantitative learning style value for each of the five dimensions.[15]. Each dimension answers five questions that are summarized in Table 1.

Numerous studies have investigated the capability of asynchronous learning networks (ALNs) to provide an effective learning environment. The result of the studies consistently shows that for courses that incorporate ALNs, student performance using ALN resources can be comparable to the traditional classroom-teaching environment.[8]

ALNs provide an appropriate opportunity to apply the learning style concept to student learning, since these modules can be specifically designed to accommodate different learning styles. Another advantage of tailored learning modules is that they allow for controlled student testing to measure the impact of specific design changes. This study uses learning modules to test the impact of the learning environment to student learning.

Table 1. Five Dimensions of Preferred Learning Styles (Felder)[15]

Alternative descriptors	**Dimensions**
Sensory (external)	Perception (what kind of information)
Intuitive (internal)	
Visual (pictures, graphs and demos)	Input (which sensory channels are preferred)
Auditory (lectures and sounds)	
Inductive (principles from data)	Organization (of information)
Deductive (consequence from principles)	
Active (action and discussions)	Processing (of information)
Reflective (introspection)	
Sequential (small steps, linear)	Understanding (preferred form of progress)
Global (large steps, holistic)	

III. Assessment Instruments and Procedure

Learning Modules in this study are tutorial lessons that are assessed via the web, as asynchronous learning networks. These ALNs are "bite-sized" lessons that are intended to be used in one sitting. Versions of the modules were specifically designed to appeal to students with different learning styles. This study analyzes the understanding dimensions of a preferred learning style, which focuses on the characteristics of sequential and global learners. In general, sequential learners are linear, orderly and learn in small, incremental steps. Global learners are holistic, systems thinkers, and learn in large leaps. These differences are expanded in Table 2.

Four testing instruments were used: the Felder-Soloman LSI, quizzes to assess learning after specific lessons, examinations at the end of the four-week session and at the end of the course, and the student satisfaction survey that is also taken at the end of the session. The Felder-Solomon Index of Learning Styles was used because it targets issues relevant to engineering education, and it makes a clear distinction between global and sequential learners. Quizzes were developed for the assessment of the information presented on specific modules, and examinations covered material from the module set. These quizzes were the basic tool to assess how much each individual student learned from each module, and to determine the module's impact. The final examination provided feedback on the effectiveness of the total learning system that included the learning modules, lectures, and quizzes. The student satisfaction survey was used to inquire about subjects that are exclusively internal to the respondents, and to enable the students to express their feelings regarding the learning experience. Although questions about their attitudes, opinions, expectations, and intentions were covered, the focus of the survey was to assess the students' overall satisfaction. The following criteria were used to determine satisfaction: (1) usefulness in preparing for the examination; (2) value of the Learning Modules; (3) type of experience compared to traditional instruction; (4) attitudes toward having the entire course taught in this fashion; and (5) helpfulness of LSI if the incorporation of learning styles helped them.

Table 2: Characteristics of Global and Sequential Learners (Felder)[15]

Sequential Learner	Global Learner
Left-brain	Right-brain
Words	Images
Numbers	Patterns
Parts	Wholes
Sequential	Simultaneous
Linear	Patterns
Detail	Whole-Picture
Verbal	Non-verbal
Punctual	Without sense of time
Organized	Creative, Intuitive, Spontaneous

Three methods were utilized to assess the impact of module learning style design to students based on their individual learning style: split-plot analysis, correlation, and analysis of student comments. The primary statistical method was the Split-Plot Analysis, in which all the students are characterized as either global or sequential. A statistical relationship between the type of student and the treatment received is assessed. The split-plot analysis was utilized to determine the random nature of the data collection using SAS software. A secondary method utilized was correlation. Is there a relationship between learning styles and learning in modules that are designed to be consistent with the student's learning style? If there is correlation, individuals with a strong learning preference will exhibit greater learning improvements with modules designed for that learning preference. An advantage of this approach is that the relationship can be graphically displayed. The third method used comments made by the students to provide a qualitative description of their reaction to the learning modules.

The ALN tutorial modules were used in a graduate/senior-level elective electrical engineering course (EE326 - Fiber and Integrated Optics) at the University of Missouri – Rolla.[2] A common perception exists that engineers are sequential learners. However these students had a wide range of learning style scores and a slight majority were global learners. Most students had scores that were mildly global or sequential. As shown in Figure 1, the distribution on the sequential/global scale follows the normal distribution. This was not an expected outcome since there was a homogenous group (i.e. engineering students). No correlation in student background and preferences was found among undergraduate or graduate standing, grade-point-average, and learning style rating.

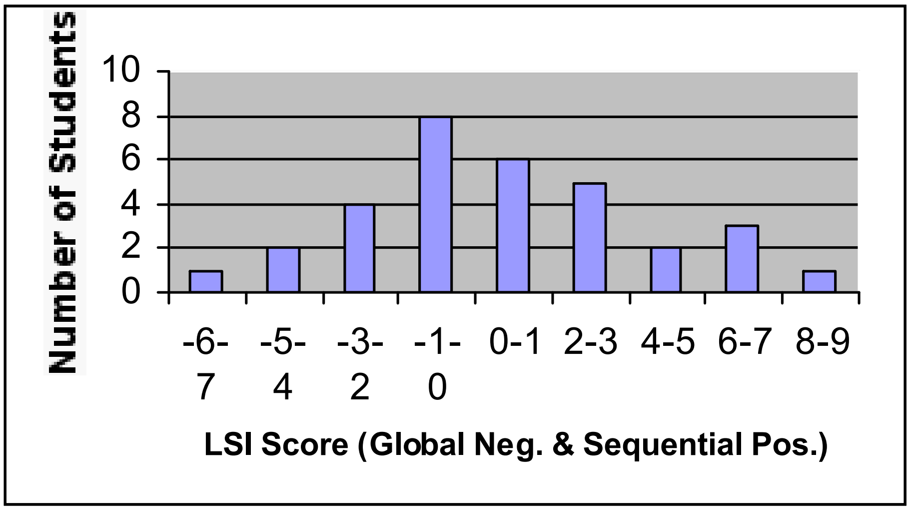

Figure 1. Distribution of Students by Sequential/global learning styles. Negative scores indicate a global preference and positive a sequential preference.

The tutorial portion of the class lasted four weeks and was designed to provide a functional knowledge of basic concepts, terminology, and mathematics in optics using an Electromagnetics approach. These web-based tutorial modules were developed in two slightly different versions - global and sequential. Both versions covered exactly the same material and the text presentation was nearly identical. However, the global modules provided a larger perspective of the lesson through more supplementary graphics and provided greater control of the learning experience through more navigational choices than the sequential modules. This control allowed global learner to decide what order information would be presented. The sequential modules gave the students a single, linear presentation of material in detail. Only essential graphics were included. Global and sequential module characteristics are contrasted in Table 3.

Table 3. Characteristics of Global and Sequential Learning Module Pages.

Characteristics of a global module	**Characteristics of a sequential module**
Images	Words/Text
Simultaneous	Step-by-step
Creative	Organized
Patterns or Non-Linear	Linear
Holistic (Big Picture)	Detail
Inductive	Deductive
Several Options or Paths	One Path

Figure 2 shows the research study process used during the first four weeks of the course. The Learning Style Inventory and a general content pre-test (Quiz 0A) were given at the beginning of class. The first module was common and had a balance of global and sequential characteristics. It gave the students familiarity with the web ALN environment and the quiz procedure. For the second and third modules, the students were divided into two groups. Each group experienced one global and one sequential module. The students were given quizzes after visiting the web tutorials, i.e. Quizzes 1A, 2A, and 3A, and after a subsequent common lecture, i.e. Quizzes 1B, 2B, and 3B. Examination 1 contained a sampling of the quiz questions and all pre-test questions. Hence, the strongest effect of the differentiated learning modules should be in Quizzes 2A and 3A.

IV. Experience of the Engineering Students

The participants in the study were thirty-two electrical engineering and physics undergraduate and graduate students from the University of Missouri-Rolla who enrolled in Electrical Engineering 326: Fiber and Integrated Optics. The tutorials covered three areas: (LM1) review of the pre-requisite electromagnetics knowledge, (LM2) overview of optics technology and concepts, and (LM3) presentation of fundamental mathematics and physical laws. The content objective of the introductory tutorials was to establish a common background of concepts, conventions, and mathematics. The students had varied backgrounds in the area. Students with less experience could spend more time with the modules and students with more experience could just review the information. The follow-up lectures and the quizzes provided reinforcement and encouragement. The web modules were available throughout the semester for reference.

The student survey indicated a high level of satisfaction with the ALN approach. The main criticisms were with technical difficulties concerning web site access. The positive results may be partially due to the Hawthorne effect, in which individuals perform better simply because additional attention is paid to them. Also, the overall performance of the students in the course was comparable with or slightly better than prior semesters.

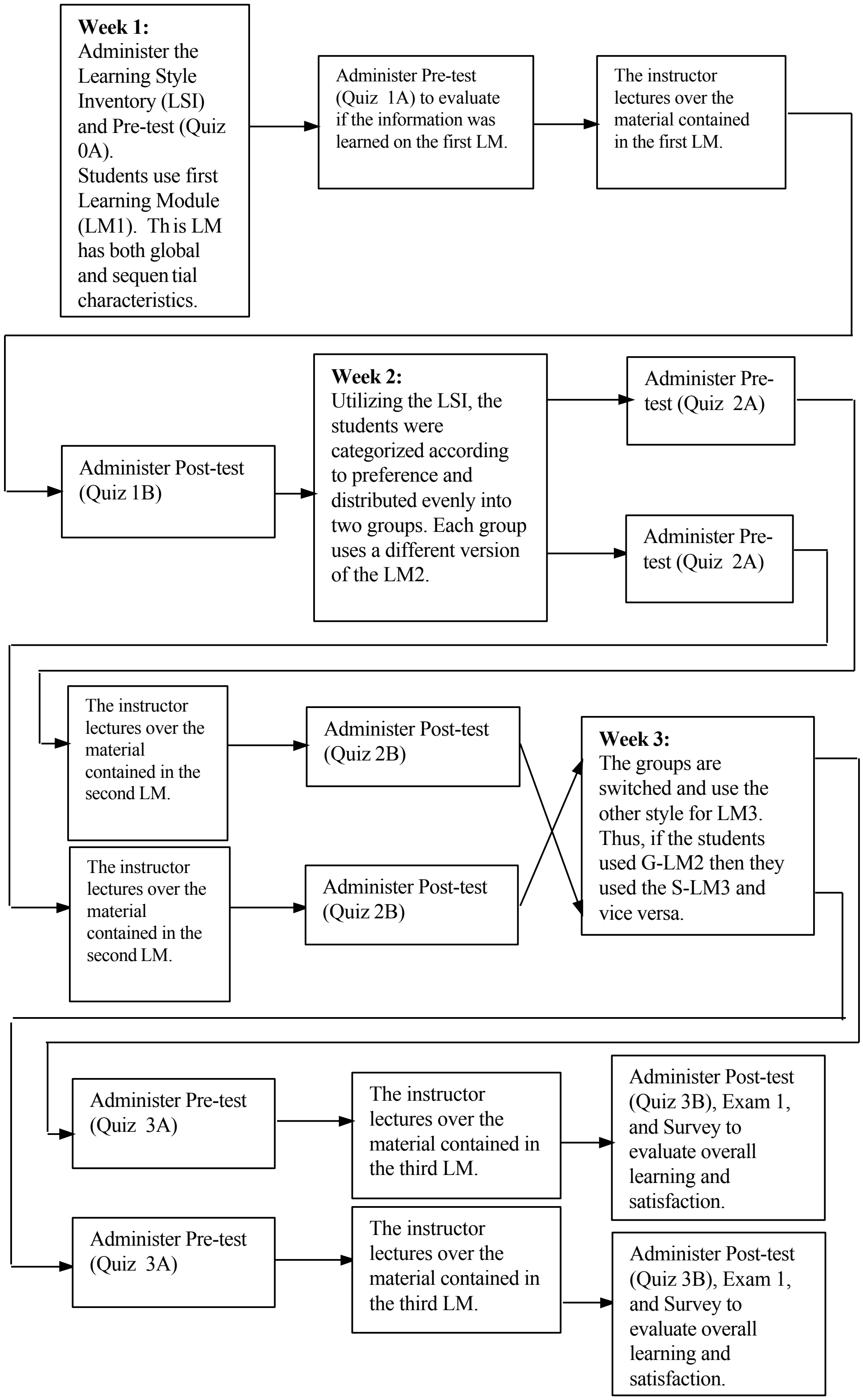

Figure 2. Flow chart of the research study process

There are some additional findings that should be highlighted in this research study. First, the general trend was that the students performed better on the quizzes after the information was taught by lecture. This trend was consistent throughout the study. Second, based on the student responses, they thought that Web-based education (e.g., Learning Modules (LM)) was an effective method and should also be used for other courses. Some students commented that the structure of the learning module process promoted an understanding of the material to be learned. They also mentioned that looking at the information and being tested on it before the lecture gave them greater insight into the important points of the lecture. Third, the surveys showed that the tutorials were especially well liked by the international students. They seemed to benefit from having a comprehensive source of background information to supplement the lecture. Some felt more comfortable with written English verses spoken English.

V. Implication of Results

LM3 and Quiz 3A results provide the best insight into the impact of learning styles to student learning. The data for the second module was invalidated due to some procedural irregularities. Also, the second module dealt with more qualitative concepts while the third module was more mathematical in content. Recall that the first module was not differentiated by learning styles. Quiz 3A results show that the average global student gained a better understanding on the material when they used the global learning module. The average test score increased from 4.8 to 6.0 out of a possible 10. Similarly, Quiz 3A results show that the average sequential student did better after the sequential module than after the global module. The average scores increased from 3.8 to 9.5 out of possible 10.

To gain more insight into this relationship, the correlation between the student's "globalness" and their quiz results was analyzed. Before Quiz 3A was given, all the students viewed a tailored learning module. Some were assigned the global module and the others were assigned the corresponding sequential module. As shown by the Quiz 3A Score verses Globalness scatter chart in Figure 3, global students received higher scores than sequential students after covering the material in a global module. The quiz scores were normalized to simplify the comparisons. Sequential learners, defined by their negative globalness scores, tended to perform worse than global learners. In addition, strongly global learners performed better than moderately global learners.

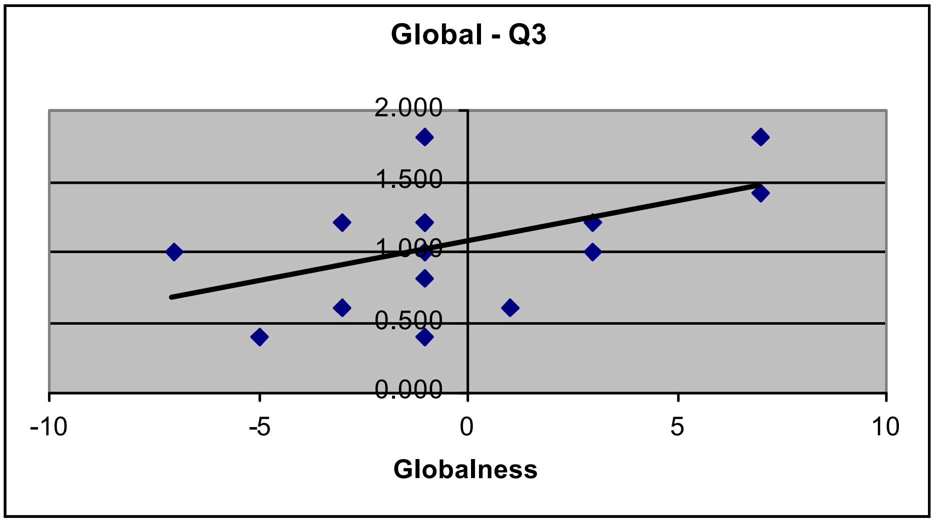

Figure 3. Normalized Quiz 3A scores after the global module. A linear least-squares-trend is shown.

This regression relationship is significant to the 0.05% level, as shown on Table 4, the analysis of variances (ANOVA).

Table 4. Analysis of Variances (ANOVA) Q3 global module.

	Degrees of Freedom	Sum of the Squares	Mean Squares	F-Value
Regression	1	53.736	53.736	4.665
Residual	14	161.264	11.519	
Total	15	215.000		

Similarly, sequential students received higher quiz 3A scores than global students after covering the material in a sequential module. Figure 4 shows the Quiz 3A Score verses Globalness scatter chart for the sequential module. The more negative the globalness score, the better they performed. However, this relationship was not significant to the 0.05% level since the F-value was 3.241, and a value of 4.84 was required. Even though the analysis does not provide the statistical validation at the 0.05% level, it does point towards a negative relationship.

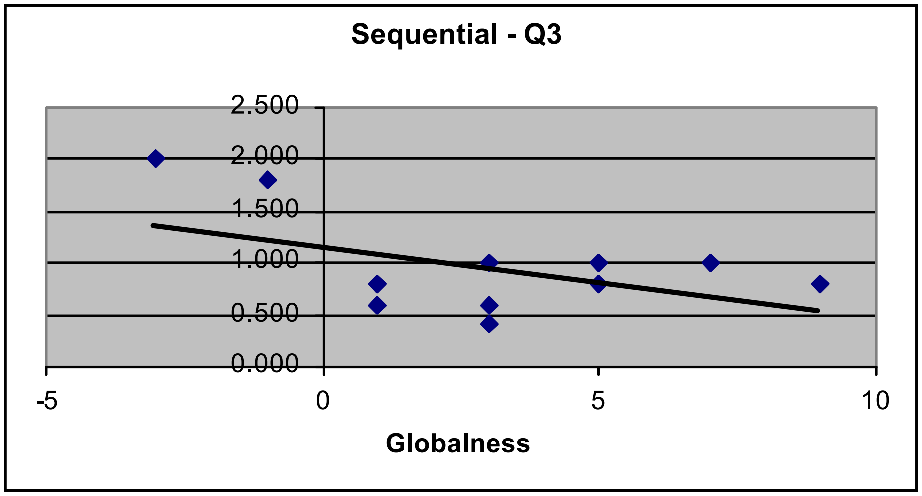

Figure 4. Normalized Quiz 3A scores after the sequential module. A linear least-squares-trend is shown.

In order to explore possible statistical inferences, a split-plot analysis was performed. In this approach all students are characterized as either global or sequential. The split-plot analysis was used to determine the random nature of the results obtained and thus assess the likely interaction between the students' learning styles and the type of learning module that they were assigned. Table 5 shows the interaction is significant in the 0.05 level, verifying that the characteristics of the learning module does affect student learning based on their learning styles.

Table 5. Interaction between LS and Learning Modules

Source	DF	Sum of Squares (sec)	F-Value	PR>F (alpha = 0.05)
LS	1	8.768	1.60	0.211
Logname (LS)	28	128.482	0.84	0.687
Method (LM)	1	.0369	0.07	0.796
Method(LM) * LS	1	61.480	11.25	***0.001***

VI. Summary

For even the weakly differentiated modules, learning styles tended to make a difference in educational satisfaction and in the ease of learning. These results indicate a potential opportunity for enhancing education. If learning style makes a difference, educators should avoid an environment that favors one type of student over another. Educators could understandably teach from their own learning style. Also, stereotypes about the learning styles of a class should also be avoided. For instance, educators that would expect our electrical engineering students to be sequential would have been wrong. In the context of asynchronous learning modules, the design should facilitate flexibility of use. Navigation should provide a preferred path for the sequential users and hyperlink options for the global users. Text and graphics can be separated into side-by-side frames so that viewing can be user tailored. Note that both of these recommendations illustrate advantages of computer-based modules over traditional printed resources.

Various strategies could be taken to apply learning styles to education. One approach, which is recommended by Felder,[15] is to develop learning environments that are balanced for the various learning styles. With this strategy, lessons are not designed for specific learning styles, and all students find parts of the course to fit their learning styles. It also encourages all the students to develop their ability to deal with lessons in other learning styles. This could be useful since the students might be forced to learn using those learning styles in future situations.

Another approach is to identify and accommodate the learning styles of the target group of students. This can be done by segregating the students so that they might take part in those lessons designed for them. Similarly, the lessons can be asynchronous, and students are assigned to the modules that fit their learning styles. However, given the flexibility of design inherent in asynchronous learning modules, the users can be given choices so that they can choose the style that they would desire. This way, the educator does not have to identify the students learning styles. By allowing the students to choose from alternate learning modules, an opportunity could be created to improve learning effectiveness. The interactive nature of many modes of asynchronous learning enables the learning environment to adapt to the needs of the individual learner, not only in the rate in which material is covered, but also with the learning environment itself.

Clearly these issues have not been resolved with this study, and much remains to be determined. The results should be confirmed in larger studies and with more pronounced module differences. Future research can identify the impact to learning of the other dimensions of learning styles. It can address the effectiveness of the approaches described above. In addition, there is a question whether effective education should focus on the student's preferred learning style. As Felder has commented, it might be important to develop the other learning styles to provide the student greater capabilities for future learning in situations in which their preferred learning style is not appropriate or unavailable. It would seem that for effective training where content is to be learned, utilizing the preferred learning styles would yield faster results. However, when the long-term objectives of education are sought, research is needed to develop effective strategies.

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