Using In-Class Teamwork Learning Modules in Digital Systems to Improve Conceptual Understanding

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Abstract

The pedagogy associated with using in-class Teamwork Learning Modules (TLMs) has been used to improve understanding of key concepts in Digital Systems. TLMs can be incorporated into current Digital Systems courses with minimal changes to existing curriculum. The process is based on students working with each other to solve digital systems problems while providing rapid feedback from the instructor needed to strengthen proper understanding. Results from the past 5 years will be presented to give a better understanding of how to appropriately use TLMs in Digital Systems and other similar courses.

Introduction

The University of Arkansas – Fort Smith (UAFS) is an open admission institution with strong ties to local industry; it supports many technology related programs. UAFS in conjunction with the University of Arkansas - Fayetteville (UAF) offers bachelor degrees in Electrical and Mechanical Engineering. The Fort Smith campus is responsible for the first two years of the degree and additional interactions with senior design students. One of the sophomore courses regularly instructed by University of Arkansas – Fort Smith is Digital Systems. In order to comply with the Arkansas Department of Higher Education (ADHE) ruling to reduce the total number of hours in the bachelors' degree, a departmental decision made in 2007 resulted in placing first-year engineering students in the Digital Systems course. This shift was implemented fall 2008; traditionally Digital Systems student's had completed one year of university work which included calculus I before taking this course. Lack of academic maturity seen in these students prompted the author to rethink how the course was taught and look for better ways to convey course content other than standard lecture format. This paper will describe the process that has evolved and show evidence of its efficacy.

Actively engaging first-year engineering students is critical to program retention and developing excitement about the profession[1,2,3]. Involving these students in one-on-one learning experiences benefits the learner[4] and educator. The student benefits from seeing how the instructor and other students think about and solve problems. The educator benefits by effectively using their time budgeted for student critical learning interactions and research with resulting greater productivity in completing project tasks.

Goals addressed by using TLMs are (1) implementation without major course changes allowing wide spread adoption, (2) encouraging peer-to-peer interactions, (3) no requirement of expensive or additional equipment, (4) ease of modification for different course topics. Additionally, TLMs should accommodate different learning styles and possess evaluation metrics; experience has shown both to increase class participation. Since many engineering students are inductive learners[5], the process can be tailored to instruct this learning style; this will allow students to learn at their own pace using a discovery method (self directed learning). TLM selection should also address class knowledge base and experience. To ensure a successful learning experience, these considerations must be addressed during the development phase of the selected TLMs. Other ancillary benefits of using TLMs are building learner self confidence, peer teaching skills, and leadership.

The remaining portion of this paper is broken into the following sections: description of TLMs, incorporation of TLMs, modification of TLMs, discussion of evaluations and results, and suggestions in selecting and implementing TLMs.

Description of Teamwork Learning Modules (TLMs)

TLMs cover key concepts in Digital Systems by asking small groups of two or three to work on an assigned problem which is handed out in-class. Each small group works on a solution for five to ten minutes before presenting their answer. To show importance for this activity, their work is taken up and graded for points to be added to their homework average. Table 1 below is an example list of concepts covered with TLMs.

Table 1: Example of Topics covered by TLMs in Digital Systems.

Topics Covered by TLMs	
Base Converting	Flip-Flops
BCD and Parity	Timing (Asynchronous and Synchronous)
Boolean Algebra	2's Complement
Boolean Gates	Adders
Karnaugh Maps	State Machines

Different styles of TLMs are used depending on the concept being covered; a topic such as converting from one base to another can be covered by having the students complete a table as shown in Figure 1 below.

Decimal	Binary	Octal	Hexadecimal
27			
	11001		
			4B
		39	
256			
			FF
		77	
	101010		
72			
		10	

Figure 1: Example of a TLM used to improve understanding of base conversion.

More complicated concepts such as state machines are addressed with open-ended design questions such as: "*Design a synchronous state machine to count from 0 to 14 by twos using either T or D flip-flops. Be sure to include a state transition diagram, state transition table, and circuit design*." A variety of TLM formats can be designed depending on topic, student needs or preferences, and conceptual misunderstandings. Instructor experience and student feedback should be used in selecting the style of TLM; more in-class time is needed for more advanced concepts.

Incorporation of Teamwork Learning Modules

A traditional lecture class instruction follows this pattern: discussion of concept (lecture), example of application (solving an example problem for the students), and assigned homework to stress understanding. TLMs can be added to the process with minimal effort while improving student problem solving skills and understanding. This is the modified pattern using TLMs: discussion of concept, example of application, assigning and solving a Teamwork Learning Module, and assigned homework. There is only one added step to a traditional lecture course; after the instructor presents a lecture and demonstrates an example of an application, TLMs are handed out to the students which work in small groups (two or three) to solve the problem. Between five and ten minutes is allotted for the groups to complete their TLM. At this point, two paths may be followed: (1) if the class believes they have a good understanding of the concept then one of the students is selected by the instructor or class peers to work the problem on the board showing their solution; (2) if the class is unsure of their work, the instructor works the problem on the board showing the solution. At this point the TLMs are collected and graded which is then added to their homework average. As noted, this adds approximately fifteen minutes to a traditional lecture, but allows peer interactions and one more exposure to key concepts. As mentioned earlier, this process requires minimal modification to existing course structure, emphasizes peer-to-peer interactions, does not require additional equipment, and can be easily modified for different course topics.

Modification of Teamwork Learning Modules

As concepts are covered each semester, classes must be assessed for learn pace and difficult concept mastery junctures. The instructor can easily make accommodations by adding or reducing the number of TLMs; additionally TLMs can be modified by increasing or decreasing the problem complexity to better match each set of students. For example, the state machine question presented in the last section could be easily modified to say "*Design a synchronous state machine to count 0, 5, 8, 3, 14, 12, 0 endlessly using either T or D flip-flops. Be sure to include a state transition diagram, state transition table, and circuit design*." As can be seen, this problem requires a more in depth understanding of the concept and is better suited for a more advanced student. TLMs should be designed for easy modification due to variation in students from semester-to-semester and understanding from topic-to-topic.

As the need arises, TLMs may be broken down into two parts, better teaching problem solving skills. For example, the state machine question above may be broken into two parts. The first part could ask *"Draw a state transition diagram for a state machine to count 0, 5, 8, 3, 14, 12, 0* *endlessly."* The second part could ask *"Complete the state transition table and K-maps need for this synchronous machine."* This process breaks a more difficult problem into smaller pieces to emphasize a method of solving a larger problem; many times less mature academic students do not possesses this skill.

Discussion of Evaluations and Results

Students from fall 2004 to fall 2010 were evaluated for the impact of TLMs on their performance in Digital Systems. Three properties are noted for evaluation: (1) number of TLMs used during the semester, (2) percentage of first-year students in the course, and percentage of enrolled students with completion of Calculus I. Figure 2 below illustrates each of the stated areas of consideration.

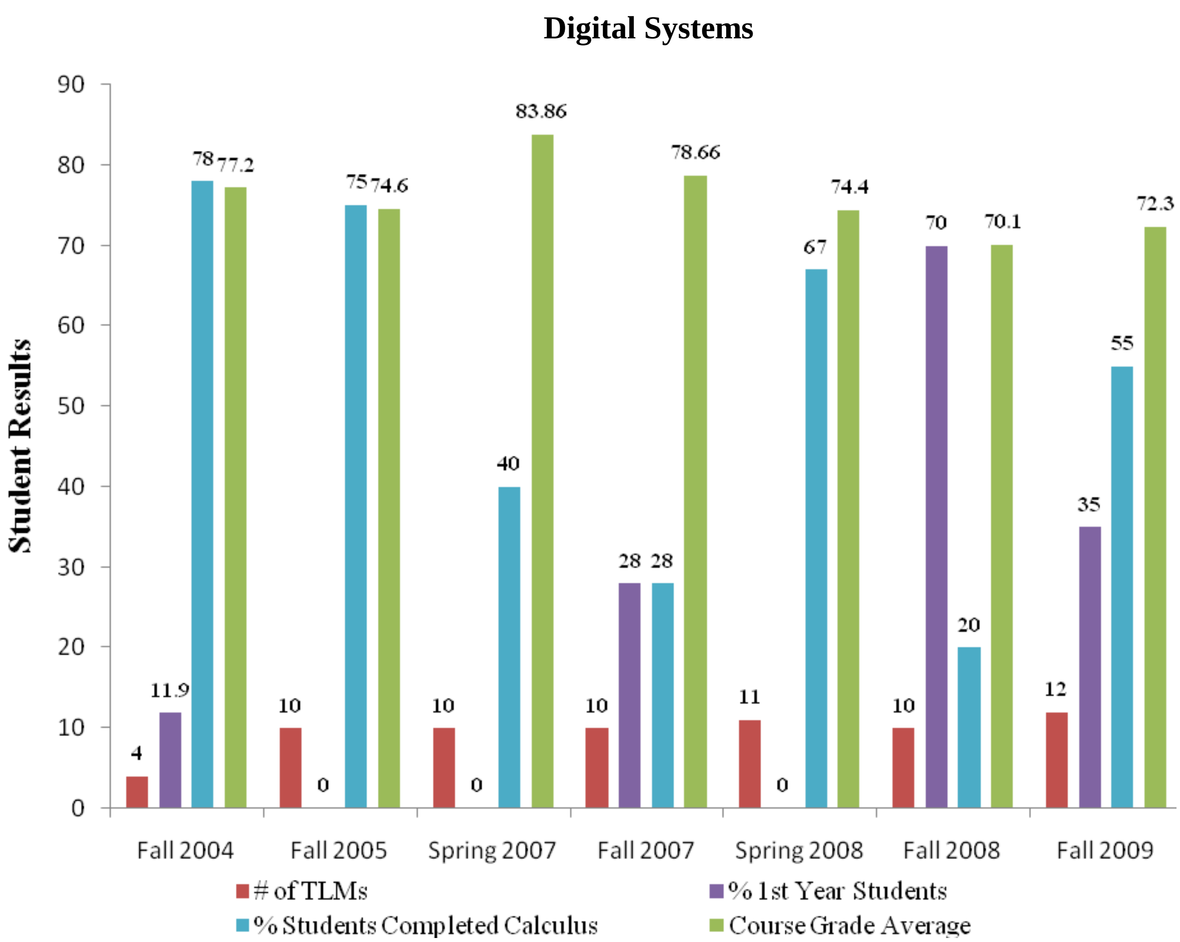

Figure 2: Course averages from fall 2004 to fall 2010 as related to # of TLMs used, % of first-year students enrolled, % of enrolled students that have completed Calculus I.

As shown in Figure 2, the percentage of first-year students enrolled in Digital Systems remained below 30% until fall 2008 when the percentage increased to 70%. Additionally the percentage of enrolled students that had completed Calculus I steadily decreased until fall 2008 when the percentage reached 20%. Note that the number of TLMs used increased from four (4) fall 2004 to twelve (12) used in fall 2009.

Two confounding factors are thought to influence final course percentage, (1) the number of TLMs used to stress key concepts and (2) academic maturity as denoted by completion of Calculus I and the number of first-year students enrolled. At the end of the fall 2008 term, the author noted that first-year students benefited from less complex, more step-by-step designed TLMs. These changes were implemented fall 2008 and fall 2009 which resulted in course averages of 70.1% and 72.3%, respectively. This course average is still lower than fall 2004 through spring 2008 but should be put into perspective of the much larger percentage of first-year students enrolled fall 2008 and fall 2009. The author believes that these students would not have faired as well without this preemptive measure of using TLMs. Fall 2008 and fall 2009 registers the lowest combined academic maturity on Figure 2. In general, the higher the percentage of enrolled students that had completed Calculus I and lower percentage of first-year students, the higher course average is noted. As inferred by Figure 2, second-year students and students that have completed Calculus I fair better in Digital Systems as they are more academically mature.

Suggestions in Selecting and Implementing TLMs

The instructor is encouraged to survey their course concepts and document ones that have low student mastery in traditional class format. Using the described methodology, TLMs can be designed, written in advance and completed as needed depending on enrolled student's capabilities, knowledge base, and academic maturity. If certain concepts are extremely difficult for enrolled students to grasp, a TLM that leads the student step-by-step to a solution may be appropriate. Instructors should use their experience and relevant feedback in making these decisions.

Implementing TLMs is a straightforward and simple process; after the TLMs are designed and written, one step is added to a normal lecture cycle as described above. It is suggested that instructors resist the urge to rush the process; if students need more than 10 minutes to complete a TLM, it should be allowed; in some cases it may be appropriate to allow the students to work on the TLM overnight. As noted, many students greatly benefit from the peer-to-peer interaction which is driven by this process. In general, using TLMs do not reduce course content coverage, but deepen understanding of key concepts without major revision to course structure.

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Bibliographical information

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