2006-2223: A SYSTEM DESIGN INTEGRATION APPROACH (SDIA) INTEGRATED INTO THE FRESHMAN YEAR

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John Hadjilojiou, Ph D., PE is a professor of electrical and computer engineering at Florida Institute of Technology in Melbourne, Florida. He is committed to the system thinking approach which he has used extensively all his life. He believes that system thinking improves quality of life by reducing variability and uncertainty, and optimizing resources. In the first year course for Computer/Electrical Engineering and Computer Science students, his students use this innovative and powerful system thinking approach as they operate as a team working together towards both generating and mastering the course material. Dr. Hadjilogiou is the recipient of the “Minuteman Plaque” from the Air Force System Command, from the Rome Air Development Center and from the MITRE Corporation, for his leadership and vision for the continuous improvement in the quality of undergraduate engineering education nationwide. The success of his SDIA approach is based on student involvement and system thinking.

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Michael G. Rywalt is a computer science student at Florida Institute of Technology in Melbourne, Florida, and an active member of Dr. Hadjilogiou’s ECE1551 Digital Logic course. He finds the SDIA approach a very effective way to learn the course material, and currently volunteered for the assignment of creating an electronic page of all the material covered in each class. This is accomplished immediately after each class, and appears in an electronic board for the rest of the students to read, comment on, and improve. This is part of the continuous improvement process emphasized in the course. Prior to Florida Tech, he entered college as an early admission student at Inter American University in Puerto Rico, graduating the high school program with honors while co-owning and operating a small family business. Michael recently returned to the mainland to complete his degree in computer science at Florida Tech.

"A System Design Integration Approach (SDIA) integrated into the freshman year"

Abstract: This research paper demonstrates that design can be easily introduced at the freshman engineering year with great success and can be continuously integrated at every level of the undergraduate curriculum. "Attachment A" summarizes the teaching/learning methodology for the first-year ECE 1551/1552 course sequence required for the freshman electrical/computer engineering and computer science students.

This design system approach [1, 2, 3, 4, 5, 6] is developed by the main author as the result of his involvement in the "Total Quality Management" revolution of the 1980s. It was a conscious effort to develop a design system methodology to obtain a solution by optimal means. It requires a new teaching methodology and an effort to overcome the unavailability of textbooks to cover this design system approach.

The SDIA is fun and exciting for both students and instructors, as each individual student becomes a contributor and co-owner of the course. During a typical class meeting, the SDIA promotes the evolution and continuous improvement of the course structure by introducing new ideas, posing new challenges, and requesting student feedback—all of which combine to yield extraordinary results. As its name implies, the SDIA is a process that aims to produce optimum design system results by meeting stated objectives, while keeping time and resource usage to a minimum. The word "analysis" is never brought up in the course sequence. In addition, a variety of technologies are used throughout the duration of the course to implement and simulate a particular design, however the underlying approach is technology independent. The SDIA succeeds where traditional educational approaches fail, and above all its greatest strength is its compatibility with any engineering discipline.

"Attachment B" summarizes the SDIA methodology which can be broken down into two phases—the first of which is used to obtain the mathematical model of the system from the stated requirements. This resultant model is then used during the second phase to implement the actual system. Under the first phase, students begin by envisioning themselves as actually being inside the box trying to obtain and describe a solution in an algorithmic model. This inspires the idea of describing the algorithmic model in a state diagram format followed by a state assignment that ultimately results in the mathematical model. Implementation is the next and final phase, where the system is designed without any degree of fragmentation.

Finally, when this approach is compared with that of a traditionally fragmented one, the student gains a true appreciation for the power of the SDIA. "Attachment C" summarizes the effectiveness of the system design methodology used in the SDIA approach.

Index term – system thinking, wholeness, integration, segmentation

I. Teaching/Learning Methodology

"Attachment A" summarizes the teaching/learning methodology for the first year ECE 1551/1552 course sequence required for the freshman electrical/computer engineering and computer science students.

The main theme of this teaching methodology is to keep the students actively involved by giving them the task of writing and illustrating their own textbook for a topic that they initially know nothing about. Writing the textbook instills the students with confidence in the development and application of their abilities; beneficial beyond anyone's expectations. By treating students as resourceful individuals with talents, intelligence, capabilities, and creativity, they will reach extraordinary heights.

Under the System Design methodology, in addition to "getting students involved" instructors need to take into account the variety of individual learning styles for each student and address every topic in a "System Thinking" manner. Also, students need to follow the "Publicize everything you do – Show it to the world" mentality, as well as the IEEE paradigm for engineering education quality initiatives for graduating renaissance engineers. Partnering with industry and other institutional departments, in addition to continuous class assessments, all need to be an integral part of the course.

This teaching methodology requires the instructor to be unique—and as such, great things can and will emerge. This is not to suggest in any way that the use of these techniques is not only proven to keep students at the university and desire to bring a friend or two, but to suggest that every professor must do something unique which students will remember and will not find at any other university. After embracing this methodology, your students will one day sit back, and say to friends or to themselves, "I feel so fortunate that I went to Your School. Those guys down there are so caring and so concerned for our future." What a win-win scenario!

It is extremely important to be unique and capitalize on the power of the current student population. The students no longer go to an institution to see the professor copy a textbook and put it on the overhead projector, burned to CD, etc.

II. Background Information

Now it is no longer necessary to wait until the senior and/or graduate level to teach embedded system design. This research work demonstrates that embedded system design can be taught at the first-year level and can be continuously integrated at every level of the undergraduate curriculum. It is our understanding that few if any engineering colleges in this country teach embedded system design principles at such an early stage. Our system teaching methodology has made this possible.

The integrated system approach is a teaching methodology that accomplishes extraordinary results. It is a thinking process that produces an optimum design, meeting the stated objectives in the minimum amount of time, while using a minimum number of resources. It produces results where traditional teaching approaches fail to do so, and can be used in virtually any discipline.

This powerful system teaching approach has been developed by the author and is used extensively in all of his courses. The first-year, first-term electrical/computer engineering class is also using state-of-the-art technologies. With the use of these technologies and the System Design approach, more material is covered with greater understanding and participation among students, producing a sense of ownership and pride. The success of this approach was carried over for the first time in the spring of 2003 with the second-term, first-year students. At that time, the system approach was used to introduce the students to embedded design principles together using the elements of the Harvard computer architecture. The success of this effort exceeded everyone's expectations. After the students demonstrated their innovative projects during the final end-of-term gathering everyone in attendance was convinced that embedded design principles should be integrated throughout the engineering curriculum.

III. System Design Integrated Approach

The system design integrated approach (Attachment B) developed by the author is the result of his involvement in the "Total Quality Management" revolution of the 1980s. It was a conscious effort to develop a methodology for increasing the retention of the material covered in the various courses. In doing that, students in their senior year use this knowledge in advanced topics without having to extensively review previous knowledge covered in earlier courses.

This effort requires change in teaching methodology and an effort to overcome the unavailability of textbooks to cover the material using this new approach. It requires the teacher to describe the goals of the course in one or two sentences and build the material from these stated goals. It also requires informing the students how the course aligns with the overall goals of their program. It is a fun undertaking where everyone gets involved as a contributor and co-owner of the course, and continuously requires refining and adopting it to the class at hand. The teacher must have great command and understanding of the material for the course, and be ready to experiment with new challenges as they arise.

Currently the author is using this approach in several courses with great success. This approach, when used in a high-tech environment, will significantly improve student retention levels as well as increase the amount of material covered. <u>This paper will outline the way this approach is used at the first-year two-course sequence.</u> It will show the technology used for this sequence and how this approach can be integrated throughout the curriculum. It should be emphasized that although our results are technology independent, some specific technology must be used by the students in order to demonstrate their final projects.

The way the material is covered makes it possible to apply this method to any course in any engineering curriculum. Once again, the key to the success of this approach is to have the instructor introduce the goals of the course in one or two sentences and to describe how this course fits in the overall goals of the program. The instructor needs to be ready to start from the stated goals and tell the students that all the material in their assigned textbook will be covered on an "as-needed basis."

The "as-needed basis" is the key to the success of this approach. The instructor needs to create the need for new knowledge and by doing this, the students are ready to accept the solution and master the new material. At the end of the term, the instructor will have time to address the students at length about how this approach covered the course material, in comparison to strictly following the textbook. As an assignment, he/she should ask every student to devise an approach to better cover the material for the course. This assignment is extremely stimulating for most of the students, especially those who thoroughly enjoyed the course and contributed toward its success.

Though it is a fun undertaking, to start the course with no prepared material and developing it while the course unfolds, it is also a challenge for the instructor to have every student participate and contribute to the course. Students under the leadership of the instructor prepare the material for the course. The instructor needs to design student evaluations for the course with their help. Three weeks prior to the completion of the course, a Master Assessment Evaluation needs to be given covering all the material taught up to that point and to expect 100 percent on each part. The student may retake a part if 100 percent was not accomplished. This gives students the confidence they need to succeed in their chosen field. With their involvement, students gain confidence and the attrition rate drops tremendously.

In addition, a need exists to create teams for accomplishing all of the requirements for the course, which results in lasting relationships among the students and builds a sense of responsibility in them.

A word of caution; while the students are working on mastering 100 percent of the material covered during the first eleven weeks of the term (if on a semester basis), the material covered the last three weeks should not be overlooked. The author made this mistake a few times and several students and the instructor were deeply disappointed. As a result, some of the students earned one letter-grade lower than expected. It was the instructor's fault and the students suffered. Additional material was covered in the last three weeks, but the instructor failed to give the students all the attention they needed in order to master it. The final exam was based primarily on the material covered during the last three weeks, since all the students had already demonstrated that they mastered the material covered during the first eleven weeks. Students had spent most of their time mastering the material of the first eleven weeks and spent very little time on this new material. As a result, not enough time was dedicated to the mastering process in the last three weeks of class. This was corrected in subsequent course offerings.

One way to avoid this would be for the instructor to not cover any new material the last two weeks of the course, concentrating only on the applications of the material to be covered in successive courses and in the Master Assessment Evaluation. Teaching with this system approach in a high-tech environment, significant time is saved and this can be accomplished.

The instructor shall have covered all material two weeks prior to the completion of the course and then administer the Master Assessment Evaluation to cover the entire course, in addition to performing other administrative duties. Those other duties include evaluating/assessing the integrated system approach with the students, while comparing it to that which the authors of textbooks follow and/or with approaches that institutions in other parts of the world are using. It is a learning experience that is worth every moment, and a process of continuous improvement that needs to be followed just like everything else in life.

In addition, use of the internet-based Blackboard software allows the students to evaluate the material covered on a weekly basis, giving the instructor a means for corrective action; another mechanism for continuous improvement—not to mention an extremely effective tool for learning.

IV. System Thinking Design Approach - The first-term of the first-year.

The traditional course coverage for a first-term first-year course in Logic and Computer Fundamentals starts with a course outline from a bottom-up approach, which is the same way our education system is structured. For example, students must take Algebra I because it is a prerequisite for Algebra II. Similarly, Algebra II must be taken because it is a prerequisite for Pre Calculus, and so on and so forth. When the time comes to use these concepts, students have forgotten them and blame past instructors and other students for their weakness. However, this is jus one fault of the bottom-up system. Another is that some topics taught are not necessary for the stated educational objectives. They are present because they have always been included, and there is a natural human tendency to fear change. Students failing these unnecessary topics drop out of school for reasons not related to their educational objectives, and it is precisely these students who will be saved with this integrated system approach to education.

The same problem existed with the way companies in this country were operating before the 1980s era. Too many departments and divisions existed within one company, increasing the cost of production. As a result, change only occurred when products made in Japan cost less to purchase than in American markets, with more features and higher reliability than those produced at cost by American companies. The same principle can be applied to education. We partition our curriculum into too many courses and each course into too many topics. As a result, <u>we have lost the value of the whole.</u> Every faculty member works hard to protect their territory (their courses) rather than working for the benefit of the overall program as one entity.

In a logic and computer fundamentals course, the traditional way is to cover the material as follows:

1. Digital Computers

2. Number Systems, Binary Numbers
3. Arithmetic Operations
4. Decimal Code / Alphanumeric Codes
5. Binary Logic and Gates / Boolean Algebra
6. Algebraic Manipulations / Map Manipulation
7. Combinational Circuits
8. Analysis and Design Procedures
9. Decoders/ Encoders/ Multiplexers/Encoder

These are the topics that are included in every course outline around the world. The same outline has been used for the last 40 years. Every author has followed the same path as the previous author, with the only exception being that as of late, they have upgraded to new software packages and started to use the world-wide-web. The fear of change has paralyzed our education system.

The integrated system approach was developed by the author after he chaired and hosted one of the first conferences in "Integrating Quality Design Principles into the Undergraduate Engineering Curriculum," February 12 -16, 1990, at Florida Tech for sixty department-heads around the country. It had the following format:

First, in the course syllabus, the only thing the students receive is the purpose of the course. For this course, it is "Analyze and Design Specialized Processors and the Introduction to the General Processor." Subsequent material follows a natural system flow process. A need is created and the material is introduced. This is done right at the beginning from the first topic covered.

The student starts out asking what a specialized processor is, and how it is described. Thus, the first topic covered is "Definition and Description of a Specialized Processor." By defining and describing specialized processors, a need arises to introduce a diagram, a table, an assignment, and a complete model of the specialized processor. As such, the second topic in this course is "State Diagrams, State Tables, State Assignment, Transition Diagrams and Transition Table of Specialized Processors." In the first few weeks, first-year students are doing mathematical modeling of a physical situation without even realizing it. Why? Because it is a natural thing for them to do. They are doing it without any resistance or questions asked. A need existed to describe a physical situation in the mathematical world and they accomplished it. Now they have a table full of zeros and ones and they are eager to draw a circuit.

In the search for a circuit from the logical table, they realize that writing equations describing the table will facilitate the transition to the circuit. Thus, the next topic is "Truth Tables (another word for logical tables), Logical Expression and Realization of Logical Expressions." After completing this topic, the students are capable of drawing logical circuits, but not yet with the minimum number of gates. They do not, however, realize this point until they are drawing, simulating, or hard wiring them on breadboards. At this stage, they are able to design the output circuit using simple AND, OR and NOT gates.

The next state condition cannot be realized without the use of devices that can remember the next state, one clock-cycle later. The students are anxious to complete the specialized design, thus the next topic is "Storage Devices (Flip/Flops) and complete design of Specialized Processors." After the completion of this topic, the students feel confident enough to design, simulate, and breadboard any specialized processor.

Next, the students are reminded that the second part of the goal for this course is an introduction to a general processor. Thus, the next topic is "Block Diagram of a Data Path and Introduction to a General Processor." The students are then introduced to the basic diagram of the processor for performing a programmed instruction in one clock cycle, or a microinstruction. The single clock cycle imposes limitations on the microinstruction set.

The data path is then described in terms of key basic blocks: namely multiplexers, "two arguments in/one argument out," "one argument in/one argument out" and decoders. Thus, the next few topics address the design of these basic building blocks. The next topic is on the "Design of Decoders and Multiplexers." They learn different ways of modeling, and then start to design them. It's easier to first describe the multiplexer in a logical expression and then draw the circuit. The decoder is easier to describe in a logical table, then to obtain the expression, and finally the circuit. At that moment, the students feel very confident in their ability to design logical circuits without ever having mentioned the term "Boolean algebra."

The next topic is the design of the "one argument in/one argument out." They learn the process of designing it under the system design approach and feel very confident with this style of delivery. The most challenging of all is the design of the "two arguments in/one argument out." Thus the next topic covers its design, which turns out to be a simple task using the system design approach. The design, however, has some special inherent limitations. Since the operation performed needs to be done in one clock cycle, it limits the number of arithmetic operations to only a single addition.

To overcome this limitation and to include the subtraction operation, a need arises to introduce a new way to represent numerical values inside the computer. This gives rise to a new system that is very natural, and in literature is known as two's complement representation. Using this representation, the arithmetic instruction repertoire of the data path is increased tremendously. The students then learn ways to design and simulate the last major block of the data path and feel comfortable with it. In literature this is known as an ALU (Arithmetic and Logical Unit).

In order for various registers to exchange information between each other, with a minimum number of wires, the "Bus Architecture and Three-State Devices" is then introduced. It minimizes the number of wires and adds structure to the overall design.

So far, the students have been introduced to the concept of the register as a collection of flip-flops. However for the general processor, the working registers have additional dedicated special features; namely, load capabilities, increment capabilities, clear capabilities and others. The design of these registers follows the same design process used in the design of one argument in/one argument out boxes of the data path. The next topic, "Registers and Counters with Special Unique Capabilities" puts these concepts together. These working registers exist in every general processor. To minimize the number of registers in any design, the information needs to be stored in a memory, which is logically a set of registers staggered together with a common address, a data register and with read and write capability. Thus, the next topic is "Memories." They learn the internal design of memories and ways to interact with the data path of the previous topic. At this point, the first-term first-year students feel good about their logic hardware design experience. Their designs do not use the minimum number of gates, which have a direct effect on the complexity and in the reliability of the design. For the students to be able to minimize the number of gates and to minimize their overall design for ease of building circuits on breadboards as well as simulations, the students get involved in the "Minimization" process. The need is real and the students master that material effortlessly. Why? Because the reward is great. It simplifies their design and reduces their breadboarding and simulation time by more than 70 percent.

To add structure to their design, the students are introduced to "Programmable Logic Array, Programmable Array Logic Devices and VLSI Programmable Logic Devices." It is a canonical representation with unique structure and flexibility.

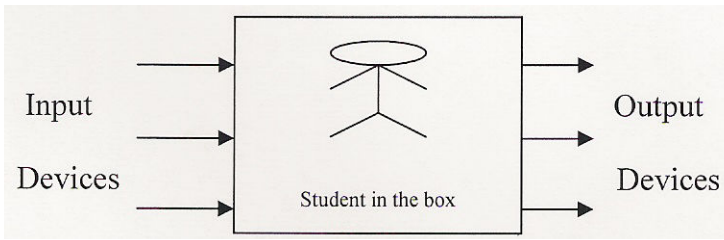
Finally some state-of-the-art software is introduced for simulation. Xilinx software is used for simulation and as an introduction to the design process of Field-Programmable Gate Arrays (FPGA).

By comparing these two approaches, the reader should be convinced that in the system design approach no topic was introduced without first creating a need for it. The traditional way followed by other institutions introduces the basic material first with the anticipation that at the end of the course they will put the whole thing together and that it will have a perfect fit. However, in many instances, traditional approaches do not produce optimum results.

The system design approach keeps the students involved, and he/she needs to master the entire process if they want to pass the course. From the beginning, the course focuses on the design of a system with the needed components rather than in the design of individual components that eventually will be put together to form a system.

In the system design approach, students cannot pass the course unless they have a strong understanding of the system and its requirements. There is nothing to memorize, only mastering the design processes for the system. The systems are complex and vary in specifications; thus, memorization is not a choice.

The greatest thing about this approach is that as soon as the specification of the problem is stated, the student is placed inside an empty box as shown below, and they need to express, in their own words, the process that they have to follow to solve the problem.

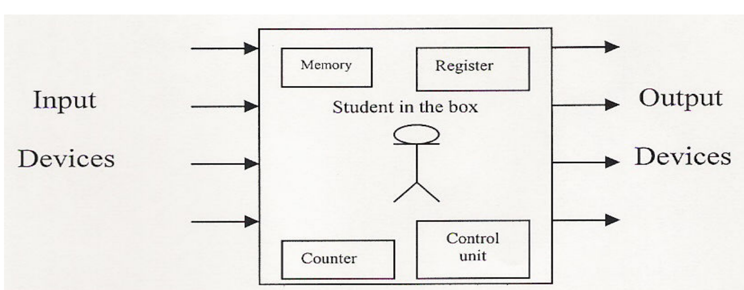


Empty box ready to be filled with hardware to meet the design objectives.

Verbalizing and documenting the process in words is challenging, but necessary, and is the only way to get to the optimum solution, and to get out of the box. After verbalizing the process, they draw a flowchart with the minimum number of states. This is accomplished by allowing them to introduce another state only if necessary. Then the assignment is done which results in the transition table, and subsequently to the complete implementation. For the first-term course, the box that they are in is empty and thus they have to design the hardware components to implement the process. Thus, in this first term, the students become proficient in hardware design from the system design approach. The students become very familiar with the hardware, since they have designed, simulated and breadboarded it.

V. System Thinking Design Approach - Second-term of the first-year.

The system approach is also used for embedded design at the second term of the first-year. Again the students are placed in the box, but this time the box is not empty. The box has plenty of resources that the students must use to obtain the solution to the stated problem. The resources in the box are the elements and the architecture of the computer embedded in the box as shown.



A box full of resources ready to be utilized for meeting design objectives.

With this new capability and environment, the students are face-to-face with new challenges and opportunities namely:

a. Input devices and interfacing with the box.

b. Acquiring a good understanding of the resources in the box, and their uses, in order to develop the flowchart for meeting the stated objective.

c. Output devices and their interface with the box.

To accomplish part a., students are introduced to input devices. Switches are very basic components with a wide variety of configurations. However, the students need to experience some of the switches characteristics in a laboratory environment. Temperature switches, analog input devices and keypads were used in most of the projects. For the part c the students are introduced to output devices. In their projects, students primarily use alphanumeric displays as output devices, along with LEDs and seven segment display drivers.

The most challenging part of the course is to properly use the resources of the embedded system to meet the stated objectives. First they start with an interface with the input devices to program ports as input ports and the hardware equivalent of that action. Then they configure ports as output, and the hardware equivalents. Lastly, and more time consuming, is to understand the elements inside the box, their interconnections and architecture. The students realized that for speed considerations they need two separate memories with different width, various dynamic working registers, the bus architecture, the need for delay loops, and the need for interrupts and timers. They are also made aware of the need for asynchronous communications and communication between a slow and a fast device. They are able to utilize these concepts starting from a simple application with elementary features, to more advanced features. Again, a need is created and the material is introduced and mastered. With such a challenging environment everything is verbalized and the solution is then implemented. First, the solution is flow-charted and then coded. After coding, the normal process is followed to load the program to the memory, and test the solution. If it worked then celebrate or else do some troubleshooting. Among the projects given were: -

1. Introduction to MPLAB, Quick-Board, HyperTerminal.
2. Intro to assembly coding (Port initialization set I/O to turn on LED's)
3. Intro to creating delays (loop delays for denouncing)
4. Intro to addressing modes (Immediate, Direct, Index)
5. Review on all instructions/processes learned
6. Intro to LCD Initialization & creating timer delays (send characters to LCD use of Direct addressing)
7. Advanced LCD & timer delays. (Calculate exact delay for scrolling of text use of Index addressing)
8. Intro to Keypad scanning (On key pressed the number will show up on LED's in binary)

9. Integrate Keypad & LCD (Security Code)
10. Continue of Keypad & LCD integration
11. Review of on all instructions/processes learned, Student Project

VI. Technology Used

The internet-based Blackboard software is a key technology used. Communication is done through this system, and is used extensively at Florida Tech to enhance teaching.

In brief, Blackboard is a course content delivery and learning management system. It provides instructors with the ability to make course materials available on the Web, to gauge students' knowledge and progress, and to enhance communication between students and instructors, as well as among students themselves through the use of discussion lists, a built-in e-mail system, class announcements and various utilities. Courses in Blackboard are delivered via the Internet in a Web-friendly format, such as HTML, without the need for the faculty member to know any complex programming.

Blackboard provides the following core features and functionality:

- Personal information management tools
- Content management tools
- Course communication and collaboration tools
- Assessment tools
- Academic Web resources
- Course management tools

In addition to the features listed above, Blackboard offers advanced features that give faculty members the flexibility to enhance their courses through the use of interactive Microsoft PowerPoint presentations, sound, video, animations, and access to offline content such as CD-ROMs that are supplied with the students' text.

Through Blackboard students were communicating with the instructor and among each other. It is the key technology used to communicate and store data, and saved plenty of class time.

Xilinx software was used for the first time with our freshman students. Xilinx is the leading provider of programmable logic solutions. The company's products help minimize risks for manufacturers of electronic equipment by shortening the time to develop products and take them to market. Students are designing and simulating their logic prototypes with Xilinx programmable devices. Their product is applicable to a wide range of markets, including data processing, telecommunications, networking, industrial control, instrumentation, consumer electronics, automotive, military, and aerospace.

Even though Xilinx is very advanced for these students, they are able to handle the basic simulation component of it. The remaining features will be mastered in subsequent courses. For the students, it is extremely rewarding to experiment with an industrial software package from a leading manufacturer.

MPLAB is Integrated Development Environment of Microchip Technology, Inc. that is used in the embedded design course along with the PIC18F452. It contains a Windows based compiler called MPASM. This powerful tool facilitates writing code in assembly language and compiling the code, thus converting it to a .hex (hexadecimal) file. We can then load the hexadecimal file into the PIC using HyperTerminal software.

MPLAB also has advanced features like programmer's editor, project manager, and step-by-step debugger. It has memory and register visibility, and supports PIC12/17/18 families and dsPIC(tm) micro controller devices. It additionally supports the use of a separate C compiler.

VII. Internal and External Assessments

a. Independent Internal Assessment.

   The SDIA approach has been validated independently by collecting data from 45 students taking this course, in which their professor used the integration approach (results shown in column 1 of item d. below), as compared to students from another course in which the professor used the traditional approach (results in column 2 of item d. below). The course assessment questions, answered by the students, were from the same category used by the department for accreditation purposes. The scale ranges from 5 being the highest satisfaction rating, to 1 being the lowest. Descriptions of the assessment criteria are described in item c., together with the tables that compare the results of this assessment study (item d.). An independent person not associated with the course or instructor conducted this assessment in class.

b. Independent External Assessment.

   The independent external assessment was conducted by a group of 20+ graduate engineers from accredited universities across the country. They are employed by a large Application Specific Integrated Circuit (ASIC) company in the Melbourne area, with approximately 10 years of experience. They design high-level communications system processors for commercial and military applications. The results of their assessment of the SDIA approach are listed in column 3 item d., and for comparison purposes, the results of their assessment of the traditional approach are listed in column 4 item d., below.

c. Description of the Criteria Used

A. An ability to apply knowledge of mathematics, science, and engineering.
B. An ability to design and conduct experiments, as well as to analyze and interpret data.
C. An ability to design a system, components, or process to meet desired needs.
D. An ability to function on multi-disciplinary teams.
E. An ability to identify, formulate and solve engineering problems.
F. An understanding of professional and ethical responsibility.
G. An ability to communicate effectively.
H. The broad education necessary to understand the impact of engineering solutions in a global and societal context.
I. Recognition of the need for, and an ability to engage in life-long learning.
J. Knowledge of contemporary issues.
K. An ability to use the techniques, skills, and modern engineering tools necessary for the engineering practice.
L. An ability to integrate hardware and software.
M. An ability to use computers for design, synthesis, analysis, or communication.

d. Data for All the Various Assessments

Criteria	1. Internal: SDIA	2. Internal: Traditional	3. External: SDIA	4. External: Traditional
A	3.98	3.80	4.00	3.50
B	3.71	2.50	5.00	3.50
C	4.31	2.90	4.50	4.00
D	3.16	2.40	5.00	3.00
E	3.87	3.30	4.00	4.00
F	3.43	2.90	5.00	4.00
G	3.34	2.80	3.00	3.00
H	3.50	2.80	4.00	3.00
I	3.73	3.00	4.00	3.50
J	3.26	2.70	3.00	3.00
K	3.87	3.40	5.00	3.50
L	3.51	2.90	3.50	3.00
M	3.89	2.70	4.00	3.00

The above table gives a clear picture of the advantages for using the SDIA approach.

VIII. Research Summary

Our research work at the freshman level demonstrates that by using SDIA, system design methodologies can be integrated into the engineering curriculum as early as the freshman year.

IX. Acknowledgement

Special thanks to all our students who, for the last 14 years, have assisted us in development of this system approach. Also, thanks to all those who assisted us in mastering the principles of total quality management over the last 25 years.

Attachment A

Teaching/Learning Methodology

ECE-1551/1552 Teaching/Learning Methodology To Enhance Quality In Engineering Education

- Get Students Involved
  - Participative
    - Create Teams
    - Make Their Contribution Visible
    - Continuous Praise
    - Continuous Joy In Learning
    - Make Them an Indispensable Part of the Whole
    - Continuous Striving to Raise the Bar
    - Make Everyone Accountable
    - Create Thinking Groups to go Beyond the Ordinary
    - Team Teaching
    - Student Teaching to All of their Knowledge

- Learning Style
  - We are all Different Learners and We Need All Styles
  - Need to be done for everyone – including teachers
  - It is an Awareness Mechanism

- Use Current Technology
  - Enhances their understanding of complex systems.
  - A feeling of state of the art real life education
  - Improves employability and part time employment while in school

- System Thinking
  - Thought as a System
  - Look at the Bigger Picture
  - Assume you are there and verbalize the process of getting there
  - Knowledge is Introduced on an As-Needed Basis
  - Avoid fragmentation as much as possible
  - Strive to Design the System as a Whole

- Publicize Everything You Do – To The World
  - Everything experienced in class environment should be worth publishing
  - Enhance the notion of continuous improvement
  - Look at every challenge as an opportunity
  - Handle the opportunity and share it with others
  - Improvement requires change
  - Change that is embraced by everyone.

- Create A Culture For The Course
    - Address your Culture
    - Document your Culture
    - Moral and Ethical Considerations
    - Professionalism and Entrepreneurship

- Graduate Renaissance Engineers
    - Follow well established quality attributes
        - IEEE Paradigm for Engineering Education
    - Transform Quality Initiatives to Education
        - Deming Quality Initiatives
        - Six Sigma
        - Lean Engineering

- Partnering With Industry And Other Departments
    - Is Part of the Whole
    - Increases your Horizon
    - Brings another Dimension and Credibility to the class
    - An Indispensable Part of Your World

- Assessment
    - Assessment both Quantitative and Qualitative
    - On a Continuous Basis with Visible Changes
    - Output Based on Learning Objectives

Attachment B

SDIA Methodology

An approach and a process for increasing the retention of the material covered in the various courses.

It requires the teacher to describe the goals of the course in one or two sentences and build the material from these stated goals.

The teacher must have great command and understanding of the material for the course and be ready to experiment with new challenges.

It should be made clear that although our results are technology independent, some specific technologies need to be used by the students to demonstrate their final projects.

The way the material is covered makes it possible to apply this method to any course in any engineering curriculum.

The instructor needs to be ready to start from the stated goals and to tell the students that all the material in their assigned coursework will be covered on an "as-needed basis."

The “as-needed basis” is the key to the success of this approach.

The instructor must create the need for the new knowledge and by doing so, the students are ready to accept the solution and master the new material.

At the end of the term, the instructor will have the time to address in detail with the students the approach followed to cover the course material and compared to that of authors of existing textbooks on the same subject.

As an assignment, he/she should ask every student to state an approach to better cover the material for the course—a closure of the improvement cycle.

Students under the leadership of the instructor prepare the material for the course.

Attachment C

System Thinking Design Approach

- Use System Thinking – Getting to your destination the optimum way using only needed resources.
  - Verbalize the process
  - Create the mathematical description of your design on hand – which is the mathematical model for your system
  - Proceed with the final implementation

- Use the power of thinking about your students as a team working towards a common goal.
  - Assess..Improve…Assess..Improve…Assess…
  - Create teams…and more teams as needed
  - Set up high standards
  - Get Students involved
  - Bring Joy In the Classroom
  - Create Healthy Learning Environment
  - Do Things that were Never Done Before
  - Make them leaders... true leaders with Love In Their Heart

Create resonance in and outside the classroom - a reservoir of positivism that frees the best in people.

Bibliographic Information

1. Wholeness and the Implicate Order, By David Bohm, ISBN 0-415-28979-3

2. Thought as a System, By David Bohm, ISBN 0-415-11030-0

3. Unfolding Meaning , By David Bohm, ISBN 0-415-13638-5

4. On Creativity, By David Bohm, ISBN 0-415-17396-5

5. The Fifth Discipline – The Art of Practice of Learning Organization, by Peter Senge ISBN- 0-385-26094

6. "The Engineering Curriculum For 2020: Values, Variability, Improvement and Knowledge" By John Hadjilogiou at the International Conference, "Frontiers In Education-FIE" November 4-8, 2003 at Boulder, Colorado.