A Computer Design and Assembly Active Learning Project

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Abstract: An active learning activity for a computer design and assembly with practical, technical and budgetary constraints was implemented to study real-life design concepts and project-based design outcomes, supplementing the traditional lecture style, implementing a potential interview process to synthesize the innovative design ideas and requirements, and relevant academic experiences as well as perspectives. The student teams conducted extensive research, analyzed hardware/software requirements as well as budgetary constraints, evaluated various design alternatives and conducted interviews with their own questions to subsequently improve the project design perspectives. The project evaluation has illustrated the effectiveness of the active learning activity to enhance the student long-lasting educational experience, i.e., the hybrid approach was instrumental to enhance student technical and interpersonal skills.

Keywords—Computer architecture, active learning, practical design

1. Introduction

Instructional methodologies have targeted superior student learning experiences, especially under complex as well as real-life design problems with realistic constraints that may be challenging or inherently insufficient to cover satisfactorily in traditional teaching-centric educational formats. Active learning is one valuable approach to encourage students for intense research, information gathering and evaluation, and engineering design to enforce superior course content synthesis and comprehension levels. As the students lead the process, the active learning approach effectively engage students into practical as well as meaningful implementation activities of the course materials under new conditions, resulting in superior learning experiences [1, 2], higher student performances in science, engineering, and mathematics [3] and with a qualitative case-study for the USA analysis [4], in which group discussions, project as well as case study analysis, reading assignments, project papers and reflective writing are found to be the best strategies of active learning. As different active learning components were introduced, a journal-club experience as an active learning implementation in a natural science undergraduate course indicated better prepared student body to follow scholarly results in literature, where students were assigned literature reading sections complementing the regular course content and were asked to participate class discussions with a-priori written questions [5]. A medical course utilized an active learning component to achieve better relevant-rubric assessment, indicating superior learning outcomes [6]. An electronic measurement and instrumentation course involved a hands-on active learning implementation to enforce student theoretical understanding, resulting in better academic scores [7]. A civil engineering active learning activity involved management courses with a research framework and subsequent two-year research project activity, aiming to achieve better student learning experience and sustainable knowledge development [8]. A System engineering field study utilized the Lego Mindstorm as an active learning tool to reiterate handling unforeseen situations or obtaining a comprehensive system-level view of key system engineering lifecycle, yielding effective implementations of theoretical techniques covered in lectures [9]. A two-semester robotics curriculum was developed to offer various active learning components to students, including open-ended hands-on engineering design process, for superior academic and interpersonal skills [10-12]. A freshman Electrical engineering course included active learning components to design a protocol simulator and founded the final simulator product and active learning components popular, robust, and suitable for problem-based learning as well as student invention of their unique ideas [13].

Computer Architecture effective design and teaching approaches have also been studied. It was already recognized that proper applications, algorithms, architectures, and active learning were four important pillars of computer science and engineering education [14]. A three-year study about a computer architecture course illustrated significant improvements in student performances and satisfaction levels after active learning components of collaborative as well as problem-based learning methods integrated into the course curriculum [15]. Recent industrial and curricular developments have proposed project or case-study usage to apply theoretical knowledge gained in classrooms, as recommended by the electrical and computing discipline governing bodies, i.e., IEEE-Computer Society and Association for Computing Machinery (ACM) [16]. A digital logic course was successfully enhanced with active learning components.
such as hands-on laboratory activities and student team project design as well as implementation, resulting in superior student comprehension levels, critical thinking, problem solving and interpersonal skills [17]. Another digital logic course active learning implementation successfully integrated theoretical foundations to hands-on laboratory experiments and associated cost-effective visualization tools, resulting in superior student logic function demonstrations and deeper understanding of the digital logic circuits [18]. A course containing digital logic design and computer architecture utilized a major design project to effectively motivate students and to provide project-based learning benefits [19]. An active learning environment for an intermediate computer architecture course was also developed with suitable design activities in the classroom, laboratory implementations, and online assignments [20]. Computer design was introduced to students with appropriate levels of theoretical knowledge and significant hands-on design activities, challenging the student intelligence and knowledgebase for a successful completion [21]. An interactive reduced-instruction set computing processor and memory simulator was also developed to utilize active learning methods for superior theoretical concept comprehension such as multicache operations, pipelining and superscalar execution [22]. A survey study found that research-based instructional strategies including active learning are known to the electrical and computer engineering faculty teaching digital design, circuits, and electronics and that the class time implementation of the strategies seemed to be the most significant concern, possibly resulting faculty members utilize out-of-class activities [23].

This research describes an active learning activity as well as project-based design outcomes about designing a feasible computer with specific constraints during a senior-level Computer Architecture and Design course, at the Electrical Engineering and Computer Science Department of Texas A&M University-Kingsville (TAMUK), a minority serving institution. The active learning experience aimed to introduce real-life design concepts under significant constraints to supplement the traditional classroom instructions for a course in traditional lecture style, to implement a potential interview process to synthesize the project design requirements and the relevant academician educational experiences as well as perspectives for superior student problem-solving, communication, time-management and interpersonal communication skills.

2. The Computer Architecture and Design Course
The course is a senior-level core course for Computer Science and an elective course for Electrical Engineering students at the Electrical Engineering and Computer Science Department of TAMUK and is regularly offered every Fall semester. The course is a 3-credit course having 3-hour/week traditional lectures with the course materials distributed to the students. The computer architectural aspects were enhanced with organizational perspectives in terms of theoretical and practical concerns. The course actively supported two ABET outcomes: “(a) Ability to apply knowledge of mathematics, science, and engineering”, and “(e) Ability to identify, formulate, and solve engineering problems”, with pre-defined rubrics. One of the outcome (e) components included this active learning project of computer design and assembly, in addition to a separate architectural development activity.

The active learning project was implemented during the Fall semester and included twenty-one students, including minority groups such as Hispanics, African-Americans, and international students. All course students attended the traditional lectures, given by the course instructor, throughout the semester and participated in individual quizzes, short project assignments and exams, in addition to the active learning implementation of computer design and assembly.

The content coverage included the major computer architecture topics, as listed with approximate expected coverage durations: Introduction to Computer Architecture and Design (1 Week), Data Representation and Arithmetic Operations (2), Digital Logic Components (1), The instruction Set Architecture (2), Machine Languages (1), Datapath and Control (2), Memory Operations (3), Input and Output (2), and Pipelining (1). The course grading scheme and associated percentages included: Exam-I (20%), Exam-II (20%), Quizzes (15%), Projects (15%), and Final (30%). All exams were cumulative and closed book-notes, with the final exam allowing a half-page (8.5”-5.5”) handwritten individual cheat sheet. The type of take-home exam was considered but not utilized, partially the time-consuming subjects being moved to the projects. Planned and/or pop-style quizzes were given both to motivate the student timely study as well as preparedness, to test the course concepts, and to ensure attendance. Quizzes had different time durations or point values depending on subject difficulty levels or amount of time needed. It was a class policy that missing a quiz due to an unexcused absence to receive a zero grade. There were two types of projects: several individual short projects and one team final design project, both of which aimed toward synthesis of theoretical concepts and engineering analysis, design and applications in terms of active learning activities. While short projects focused on topics covered, the final design project required a comprehensive study of a contemporary issue in detail. The final project technical findings and evaluation were announced to be assessed, at the instructor’s discretion, during the oral presentation by the instructor and the classmates, if time permitted. The final course grades were to be assigned to reflect the subject comprehension scale
that was determined by the instructor.

3. The Computer Design Project

After covering major computer theoretical backgrounds and demonstrating a sample computer design activity with several constraints to exhibit the proper synthesis and implementation steps in the first half of the semester, the active learning project of computer design and assembly was assigned to synthesize innovative design ideas as well as interview questions for a working computer design, during the second half of the semester, and the students were asked to form teams with three or four students while promoting diversity with maximum mutual interactions to nurture all relevant student skills. As most teams (5) included three students, one team included four while two teams included one student each, resulting in eight different computer design. The computer design project included specific project-related technical and budgetary guidelines, and required significant theoretical as well as practical research and appropriate implementation under new situations, commercial components and corresponding specifications, project design, management and leadership, communication, teamwork, and critical as well as innovative thinking skills, a potential interview with a computer technology professional, and a complete description of the practical computer and documentation. The student teams conducted extensive research, analyzed hardware/software requirements as well as budgetary constraints, evaluated various design alternatives and conducted interviews with their own questions to subsequently improve the project design perspectives. The student teams and the course instructor maintained a constant communication as well as interaction both to monitor the team design progress and to further explore design alternatives. The student teams were asked to document their project theoretical developments with clear justifications for their choices and implementations under technical and budgetary constraints in a technical report.

The active learning project was implemented as the semester project of the course during the second half of the semester, after exposing students with the needed major computer architecture components, both in theoretical perspectives and hands-on classroom demonstrations. The project instructions included the items, listed as (in their original format)

- The term project will be completed by teams of 3-4 students who will be assigned in the class. Based on the instructor’s discretion (and time permitting), oral presentations may be required.
- The project initialization steps, detailed analysis of component selections/justifications for each specification (especially, when multiple products are available for the same specification), price comparisons, etc., MUST be explained clearly.
- All copied materials especially the images of the components used in this project must be referenced and credited.
- A separate budget table including the component names, quantities, prices, manufacturers and internet locations is to be prepared and submitted. The budget limit cannot be exceeded. Also, if the final cost is well below the budget limit, the spending selections and component choices must be fully justified.
- There will be one final team report that is to be written by using a word processor and all figures, tables, etc., are to be numbered, placed appropriately, referred in the text, etc. Clarity, organization and presentation of the report will be part of the final grade. Possible extra credit: the team prepares a list of interview questions (at least, more than ten meaningful questions) related to the project, reaches out to a professor with proper background, and conducts a short interview to explore different perspectives and choices. (Proper procedures for interview solicitation, execution, and reporting must be followed).

The project required a computer design according to the major specifications, listed below, and hypothetically assembling the working computer machine with available commercial products accordingly;

a) Each group has a total of $800 hypothetical budget that is to cover all components including the %8.25 Texas sales tax (You can assume that there is no shipping/handling costs, no rebates, and no required software purchase).

b) Each computer will have at least one Blue-Ray driver feature.

c) The computer will possibly be used for
   a. NASA Space exploration robotics system data analysis,
   b. Analysis of non-linear dynamics of robust systems, image processing, magnetic levitation systems, superscalar system simulations, etc.,
   c. Real-time hurricane monitoring sensory system data recording and webcasting,
   d. Doctoral student audio-visual class presentations for pharmacy and international economics disciplines.

d) The number of USB and Firewire ports as well as required hard-drives (including the RAID configuration) will be selected by the team with full
justification.

e) Three additional unique features that each team will decide and justify. Extra points will be awarded based on the originality and uniqueness of these features.

The project interview aimed to provide theoretical, engineering, historical, and commercial insights during the computer design by approaching a relevant professor, or any qualified computer industry professional, and utilizing the interview responses to explore different perspectives and choices. As there was a potential extra credit for the interview, the guidelines emphasized, at least, more than ten meaningful project-related questions to challenge the team technical skills and knowledgebase, and subsequent integration to the team computer design. Since the interview was potentially sensitive in terms of arrangements as well as professor availability, the teams were clearly instructed to follow proper procedures for interview solicitation, execution, and reporting. There were two teams who prepared interview questions, conducted interviews with an active computer science department seasoned instructor and a campus information technology director. Due to lack of space, the interview questions and responses were omitted.

The typical computer design required extensive team discussions about the given hardware and software specifications and their implied computer architecture requirements. Each team was allocated a total of $800 hypothetical budget to cover all components including the 8.25% Texas sales tax. As the project envisioned an active learning experience such as designing a sample computer for a large organizational upgrade, no shipping/handling costs, no rebates, and no required software purchase were assumed as they were typically offered freely by computer manufacturers or the organization continuous utilization of the same or upgraded software components.

Although the course students were not exposed to the anticipated disciplines, namely, NASA space exploration robotics system data analysis, analysis of nonlinear dynamics of robust systems, image processing, magnetic levitation systems, superscalar system simulations, real-time hurricane monitoring sensory system data recording and webcasting, and doctoral student audio-visual class presentations for pharmacy and international economics, and associated software components, they were required to conduct research on each mentioned discipline and to identify major software and hardware requirements. It was observed that the project software application specifications as well as requirements were discussed extensively among the team members and were translated into plausible computer component specifications such as the processor speed or the amount of RAM for satisfactory performance while the project hardware specifications were considered under the budget constraint. The major data analysis and program execution requirements of the applications were translated into superior processors, larger as well as faster main memory, large hard drive storage, large input/output ports as well as storage capabilities, e.g., redundant array of independent disks (RAID) and superior motherboards. Data recording or displaying operations seemed to focus on superior graphics card, suitable and mostly larger monitors, wireless mouse as well as speaker selections. It was also noticed that the input/output operations for data exchanges were overlooked to some extent while basic input/output tools were treated as part of the motherboard selection with sufficient input/output capabilities, higher clock frequency as well as higher bus data rates. When a team faced a trade-off for a component as it was expected between mainly cost and performance dimensions, it was required to fully justify the selection in terms of the project requirements, budgetary constraints, technological perspectives, etc. As there were many different component selections by the student teams, an illustrative computer design components were described.

Teams appear to consider plausible processor, main memory and motherboard combinations to support their research findings about hardware requirements under the budgetary constraints. Most teams identified a candidate processor for the expected heavy numerical calculations in project software tools and arranged the motherboard and main memory to support the superior processor operations. Although the main processor selection was Intel Core i-series and Core i5 was the top choice, as shown in Fig. 1, for their expected nominal and boosting performance levels, built-in security, superior visualization capability, and satisfactory cache sizes, there were Core i7-960, Advanced Micro Devices (AMD) FX-6300 Vishera 6-Core, AMD FX-8350 8-core processors, after some teams studied data analysis and 3D modeling benchmark results. The processor comparison was about, performance, cost, parallel and graphical processor performances, and manufacturer brand names.

Figure 1. The Computer Design Project a)-b) Intel Core i5 Processor, c) the ASUS Z97M-PLUS Motherboard, and d) Main Memory (RAM)
The motherboard selection was also critical as there were many available options. However, teams tended to utilize many motherboard features to comply with the project requirements while saving some funds for the rest of the project specifications. Teams utilized motherboards with faster chipsets for program execution as well as data exchange, with appropriate processor socket type such as LGA 1150 for Intel Core i5 processor, with a number of USB 2.0 and USB 3.0 connections, potential support for HDMI, SATA, eSATA as well as RAID configurations, reliability and precision with proper set of chipsets, potential support for the largest main memory capacity with highest data transfer rates, with largest data communication protocols and associated slot availability, easy usage and update of Basic Input-Output System (BIOS) tools, different network communication capability, and online review scores, as one of the selection is shown in Fig. 1 for the ASUS Z97M-PLUS LGA 1150 motherboard - Intel Z97 HDMI SATA 6Gb/s USB 3.0 Micro ATX Intel chipset. Other motherboards included ASUS B85M-E/CSM, ASRock H94 PRO4, MSI 760GM-P34, ASRock 970 EXTREME4, ASUS M5A97 LE, ASUS Z97-PRO LGA1150, and ASUS P8B75-M/CSM LGA 1150.

The third component was typically to identify the main memory (RAM) of the computer, supported by the motherboard clock frequency operation ranges. Since the larger the main memory the faster the computer response and there were several data operations specified by the project, teams seemed to put a lot of emphasis on utilizing the largest capacity while complying with the motherboard support and budgetary constraints. The RAM size was seen to be 8 Gigabytes with mainly DDR3 technology by all teams, as one illustrative RAM is shown in Fig. 1.

Once the three fundamental computer components were selected, teams seemed to be diverging in terms of their next components. There were high quality monitors, wired or wireless keyboard and mouse combos, and stand-alone as well as built-in speaker selections with varying output power levels, as a sample set is shown in Fig. 2. The monitors were selected by comparing the actual viewing space and associated resolution, superior display technology and power consumption levels, and were between 17-21.5 inches in size and with LCD or LED technology. Wireless keyboard-mouse combo was seen to offer flexibility during presentations, as part of the project specification, and was interfaced with the main computer via USB input/output protocol. Also, an optical mouse was preferred by one of the team to provide reliable interactions with the computer. Furthermore, some teams considered the ‘wireless’ keyboard-mouse combo as one of the unique feature. In addition, some teams preferred to emphasize the computer execution performance such that they seemed to obtain basic components, possibly to save some funds for high-end performance critical components.

Long-term permanent storage options and faster data input/output operations included magnetic disk drives up to 1 Terabytes, solid state drives, a Blue Ray driver that was specifically instructed as part of the project specification, and RAID implementations, shown in Fig. 3. As solid state drives were seen as a ‘unique’ feature, it was recognized to increase both the performance of the computer considerably and the cost of the computer, resulting in a delicate trade-offs such that some teams preferred large capacity hard disk drives instead of solid state drives. The RAID 0-1-5 implementations were obtained by preferring motherboard feature or an external RAID controller. In a design, up to four 250 Gigabyte magnetic disk drives were also utilized in the RAID 10 configuration, resulting in a 500 Gigabyte effective storage size in RAID 1, both for superior data input/output and reliable real-time data backup performance levels. Although there was only limited discussion about the required Blue Ray drive as it is a standard component, the data transfer rate, the read-write speeds, the manufacturer, and the cost were compared to decide a particular one.
Graphics card selection also seemed to be important both in terms of anticipated higher graphical operations and cost of the component. Out of built-in or external graphics cards, the student teams tried to obtain the largest graphics card memory while monitoring the project budget as graphics cards are very expensive among many required computer components, resulting in mainly external cards with 1-2 Gigabytes memory size. Video card CrossFire support was also considered as a unique feature to utilize a number of graphics cards, possibly having newer and older technologies, both to improve graphics performance and to maintain lower cost of the computer. A sample graphics card is shown in Fig. 3.

Computer cases, a sample shown in Fig. 4, were mainly chosen by studying the cost, the number of internal and external expansion slots, form factors, the number of available cooling fans and ventilation options, aesthetically-important LED lighting, and sturdy building material seemed to be supporting decision factors. Power supply of a computer, shown in Fig. 4, was also seen as an important design issue to provide sufficient and reliable amount of power for computer components. As the sufficient power capacity was seen to be the main factor to consider, the cost, the number of power cable outputs as well as connector types, power efficiency ratings such as Bronze Certified for more that 85% and Gold Certified for more than 95% power efficiency levels, reputation of the manufacturer, compatibility with processor specifications were observed to be the supporting factors for team decisions. The Webcam-microphone combo in Fig. 4 was also proposed to support the required project tasks, including webcasting operations. The webcam rotational capability as well as high-resolution sensor features were the main consideration points.

In addition, one team also proposed a laser printer as one of their ‘unique’ computer machine feature. Another team proposed an integrated processor with a graphical processor unit as part of their ‘unique’ feature set. In addition, IEEE 1394 (Firewire) PCI card was also proposed as a ‘unique’ feature, that was significant due to the Firewire input/output protocol superiority for large data transfer operations.

4. Evaluation

The computer design active learning project contributed to superior student long-lasting educational experiences under open-ended real-life design challenges under a number of constraints, highlighting its effectiveness. The team performance and project effectiveness were quantitatively and qualitatively evaluated in a number of different methods, including the technical project reports according to the rubric-based student outcome assessments, verbal reports by individual students or student teams reiterating the project outcome, and classroom as well as office-hour discussions. The participating student open-ended computer design performances as well as report content presentation or justification qualities strongly suggests a successful implementation of the active learning project, effectively providing real-life educational design experiences. The corresponding class average for the computer design project was 92.3, indicating a high level of student research and preparation performances, with a range of 83-105 (after extra credits). Thus, the hybrid approach, including both traditional and active learning components, was observed to be instrumental to nurture student problem-solving, critical thinking, time-management, technical writing, and interpersonal communication skills to integrate the computer architecture theory with real-life design experiences.

5. Conclusions

An active learning project to offer an open-ended computer design project was successfully developed in the course and implemented by the students. As the students were exposed to the important computer design principles and available commercial components as well as associated selection process justification, the active learning activity was able to greatly enhance student comprehension levels, alleviating the lack of hands-on laboratory facilities.
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6. References


