Undergraduate Research Experience: *A Case Study at ECE Department of Amrita University*

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Abstract—**It is a unique experience for the students and the teachers during the undergraduate research. The students benefit a lot as they are introduced to the analysis, critical thinking and technical aspects of the given research problem. Also this serves as one of the great ways of effective learning. For a teacher, it is a great satisfaction as this is one of the tools of effective teaching. The research work presented here discusses about the undergraduate research experience in the Electronics and Communication department of Amrita Vishwa Vidyapeetham (Amrita) University. Undergraduate students are introduced into the research stream even during their second year. Their research work, at the end of final year is considered to be equivalent to, or greater than that of Graduate students' research work. Care is given to make sure that the academics of the student are not affected because of the involvement in research work. The case study presented here includes the undergraduate students' research work who graduated in the years 2010. A total number of twenty four research papers got published from the year 2008 to 2010 at various international conferences. One journal paper and one book chapter were also published. Students got opportunity to travel outside the country to present their research work and meet expert researchers and discuss their work. Eight of these students are doing their graduate programs in various US universities.**

Keywords-undergraduate research; research experience; student projects

I. INTRODUCTION

UG research is unique in the sense that students even at the UG level are introduced to research work. But not many Universities are looking into this. Even within a University, not many departments are keen on this. For example, in the university where I am employed, only one department, that is ECE is very active in promoting UG research work. This way of introducing research work is beneficial for both students and teachers. Teachers can see themselves how far the class room taught concepts have reached the students. They are able to measure the depth of the understanding of the fundamental concepts. On the other hand students are able go deeper and deeper into their field of interest and at times wonder about similar research undertaken at various universities worldwide.

Training the students and preparing them for undergraduate research work are themselves a research challenges. The students should be motivated at all times and the teachers

should also keep them motivated. There should be proper coordination between them. One important aspect is that the students should be able to work in research area which interests them. It is found that undergraduate research work helped students become technically strong and provide them with in-depth knowledge of the chosen area of research. It also served as confidence building exercise where students are able to discover their potential and decide to continue their studies by entering into graduate programs.

In this paper we are going to present about the research experience at the ECE department of Amrita Vishwa Vidyapeetham University (Amrita University), Kollam Campus, Kerala, India. Amrita University is a multi-campus, multi-discipline, multi-state university in India, accredited by NAAC, India. As most of the universities, at UG level, concentrates on learning through class room teaching, we, at ECE dept. thought to introduce research at UG level even from the beginning of second year. The advantages and the challenges faced during such an endeavor are also discussed in this paper. Most universities in India concentrate on giving training in Corporate-Industry Relations to make the students ready for their campus interviews in the final year. Such training starts in the second year itself.

II. RELATED WORKS

The paper [1] discusses UG research experience through simulation and experiments. Most of the details are technical and gives important to technical aspect. Only few things are discussed related to UG students' research. Whereas the author in the paper [2] have given great importance to UG research, the benefits the students get, the feedback from the students and also challenges faced. Paper [3] highlights the relation between the research projects and class-room projects. The author of paper [4] presents the UG research based on a course in Mathematics. There are no significant research findings and only feedback from few students is listed.

As UG research is continuing with grand success into the fifth year since 2008 in the ECE department, this paper particularly focuses on the 2010 pass-out batch (2006 batch). About sixteen students got involved in the UG research as early as 2008. A total number of twenty four research papers got published at various international conferences. One journal

paper and one book chapter were also published. Students got opportunity to travel outside the country to present their research work and meet expert researchers and discuss their work. Eight of these students are doing their graduate programs in various US universities. The paper discusses various topics on how research projects are chosen, how the students are trained, benefits for the students, feedback about the research, their experience etc.

III. MOTIVATION

A group of nine UG students created history at Amrita University by becoming the first group of students to go outside the country to present papers at the 2008 Regional Student Conference on Research and Development, which was held at Universiti Teknologi Malaysia, UTM Skudai, Johor, Malaysia on 26-27 Nov., 2008. As part of the course CMOS Integrated Circuits EC320 during their fifth semester, they were asked to submit their ideas related to CMOS IC as term papers and the few good papers were submitted to this conference. This was only the beginning. Later many more students got involved and expanded their learning, knowledge and skills which motivated many to pursue higher education.

IV. STARTING RESEARCH PROJECTS

A. Forming Groups

During the second year of undergraduate study, a workshop on microcontrollers is offered to the students of ECE department. The workshop will usually span four to five days, where the students are taught assembly language programming, simulation tools and detailed theory of microcontrollers. The workshop will be handled by experienced faculty of the ECE department and attracts a hand full of second year students thought it is open for students of third and final years. The workshop includes theory sessions, seminars and lab sessions. By the last day of the workshop the students will have done a fair amount of programming and will have good understanding of the microcontroller concepts. At this point, the students are asked to do a mini project using a microcontroller. They will be offered simulation software and necessary hardware components to solve build this project. The students have to write their own assembly program, load it onto a microcontroller, build a physical circuit and produce the desired output.

While the workshop is in progress, the faculty will be able to evaluate the students carefully and find students who show genuine interest. After the mini project is completed, the faculty members choose students who have good potential and interest in project and research. These students are then clubbed into groups of three or four members, which may be boys alone, girls alone or mixed groups.

B. Beginner Preparation

After the students have been sorted into different groups, they are asked to do research on various fields and come up with at least five different possible mini projects. The research work is done by reading articles from journals, the internet, technical magazines etc. Once the research work is finished,

the groups have a meeting with their project guide and the research work of each of the groups is analyzed. Out of the many projects which the different groups bring forward, one project is finalized for each group after the discussion and they will be working on it for the next three months.

By this way, the students get a motivation and an opportunity to go out of their prescribed curriculum and get updated with the latest technological developments, various research projects, research papers and existing products in their respective fields of interest. This research work and their mini project will lay the foundation for higher research and projects later on.

C. Starting a Project

Once the groups have finalized on their projects, each group will have to create a design. After the design is created, the student will simulate it using CAD tools such as PSpice, NI Multisim and Proteus. The students themselves explore these CAD tools and use them to meet their requirements. By doing simulations, the students will be able to relate the fundamental concept they study in class to the actual application of these concepts in practical situations. They can cross check the results they obtain with theoretical values and get better understanding and deeper knowledge of the subject. Since these tools are not taught as part of the curriculum and by knowing these tools these students get an advantage over their peers.

If the software simulation is satisfactory, the students move on to developing the hardware of their project. The guide will hold a meeting in every three days to monitor the progress of each group. During the meetings, the students will be able to clear their doubts, express their ideas and also ask for inputs and suggestions from the guide. Each group is expected to complete their mini project within three months. Once the mini project is completed, a major research project is assigned to each group.

D. Planning

Working on one or two mini projects will give a good foundation for the students to start working on their major research project. They would have gained enough experience in hardware debugging and programming and will be able to clearly choose their topic of research which will span from one and half to two years. Even in the case of choosing the main research project, the students are given the liberty to select two or more topics, discuss with the project guide and eventually finalize on one of the selected topics. The areas of research which the students usually select come under VLSI, Embedded Systems, Wireless Communication or Renewable Energy etc. After finalizing on the topic, the students are asked to submit a detailed plan of their work. The plan should provide a detailed outline of the work the group will be undertaking from the start of the project till its completion.

E. Project Execution

The students are requested to spend between one and two hours in the evenings after class hours, on their research

project. They are given the freedom to work between four to five hours during the weekends. On usual working days, the departmental labs are open only till 5 pm. for students. However, the students who are doing research projects are given special permission to use the lab facilities till the desire.

The progress of the students is monitored every week by the guide by holding meetings once every week. During this meeting, the progress is evaluated and short term goals for the project are set. The students can also clear their doubts and ask for suggestions and help from the guide. Apart from the meetings, the guide meets the students from time to time to help them with the project work.

F. Training in Writing Papers

While the project is in progress, the students are encouraged to start writing technical papers based on their work. The students are given special training in writing papers in accordance with the existing standard formats such as the IEEE paper format. They are taught to write the paper in Microsoft Word, which is the commonly used editing tool for writing papers. The students benefit a lot from this exercise as they get an insight into how technical papers are written and will help them in writing research papers in the future. Some of the papers that the students write in this stage may even end up getting published in international conferences.

V. RESEARCH ORIENTED TRAINING

As the project progresses, students are asked to look into various IEEE papers including conference and journal papers related to their project. Even though many students find difficult in understanding the entire paper contents, group discussions along with the project guide makes easier for the students to understand gradually. They come to know about various ways in which research is carried out, particularly how to conduct experiments, measure the results and compare it with the standard one or already published results.

A. Introducing Research Module

While the students are engaged in implementing the project, a research module is gradually introduced into it. As an instance, one of the groups of 2006 batch started a VLSI project on designing a CPU module in HDL; a research module of power reduction was introduced. As a result of this a paper got published at the International conference on Parallel Processing Workshops, ICPP 2009, Vienna, Austria.

B. Experiments

The projects are not product oriented alone but also research oriented. Students are encouraged to submit papers to conferences and/ or journals. In the process they learn research, they do research and they continue with research which takes them from UG level to graduate to PhD levels. One important aspect in this process is to learn how to validate their theoretical conclusions. During this they learn about various tools, their usage, in carrying out experiments and come out with results so that they can be compared with the findings of other researchers.

The student group working on designing CPU module in HDL wanted to conduct some experiments to see if the power was really reduced after introducing the module of power reduction. The design was based on 32-bit ALU on the data path. They started with 32-bit parallel inputs for ALU, then reducing the input bus lines to 16, 8 and so on, until the input was serialized. The power variation that was brought about by reducing the input data lines was estimated using Xilinx ISE 10.1. This is followed by gating the data path with the implementation of the ALU and the power analysis for all different configurations of data input lines.
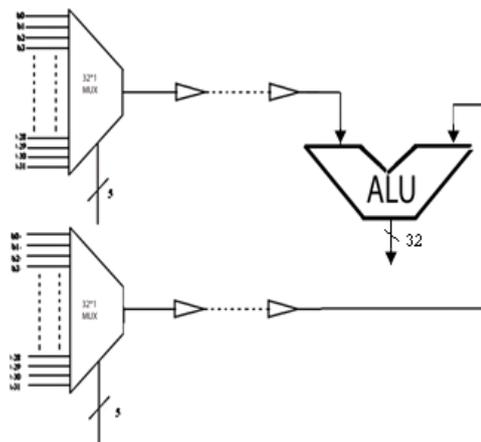

Figure 1. The ALU taking in two 32 bit serialized input

Fig. 1 shows serialization of 32 bit data. In the first stage of analysis the 32 bit data is used as such. In the next stage, 32 bit is taken into the ALU as two 16 bit data, four 8-bit data etc. till the data input is taken as a single bit data. Power analysis has been done in Xilinx ISE 10.1, the power distribution for varying configuration of bus lines are obtained as given in Table I.

TABLE I. POWER DISTRIBUTION FOR VARYING BUS CONGIGURATION

Power (W)	Bus size					
	32bits	*16 bits*	*8 bits*	*4 bits*	*2 bits*	*1 bits*
Clock (10 MHz)	0.008	0.012	0.012	0.012	0.012	0.012
Logic	0.541	0.118	0.061	0.000	0.000	0.000
Signals	0.172	0.041	0.026	0.005	0.000	0.000
I/0	0.022	0.014	0.032	0.002	0.001	0.002
Dynamic Power	0.750	0.187	0.131	0.020	0.013	0.013
Quiescent Power	0.013	0.013	0.013	0.013	0.013	0.013
Total Power	0.763	0.200	0.144	0.033	0.027	0.025

From the table it can be inferred that when the clock frequency is fixed to be 10MHz. by reducing the number of bus

lines from 32 to 16, there has been a significant reduction of power from 0.763W to 0.2 W, showing that reduction in the number of bus lines can bring about a significant decrease in the power consumed

C. Documenting Research Work

The students are asked to keep a separate note book for each of the projects and enter the details of the work on daily basis. This was one of the most effective ways in addressing or identifying various issues related to project and research work. When students start writing about their work on each day, the try to put in words what was only an idea or experience. They are trying to give shape to their ideas and experience and in this process discover various issues and solutions to various problems they face. Once a month students are asked to make a soft copy of their work mostly by Microsoft Word.

D. Publishing a paper

Once a research work has progressed well and students get significant findings in their work, they are extended help by the project advisor to identify proper conference to suit to their work. They submit a research paper as work-in-progress or as a full paper as depending on qualifying and quantifying data, maturity of their work, innovation etc. Table II gives the details of papers published at National / International conferences, conference attended etc. by the 2006 ECE batch of students. These students presented papers at SCOReD 2008, University Teknologi, Malaysia, ICCSIT 2009, Beijing, China [6], ICPPW '09, Vienna, Austria to mention few. The papers were included in IEEE Xplorer, ACM Digital Library and indexed by Ei Compendex, ISI Proceeding. Once group could even publish a paper in an International Journal [7].

TABLE II.   ACHIEVEMENTS OF 2006 ECE BATCH

Areas	Achievements			
	International conferences attended	Papers published at international conferences	Papers published at national conferences	International journal publications
	7	22	2	1

VI.   COURSE WORK: RESEARCH WORK

As per the Amrita University syllabus, there is a special course titled 'Research Works RS300' which the students could register as early as fifth semester. As per the norms, the students have to look for a research advisor and finalize their research topic. Then they are allowed to register for this two credit course. This will be an extra credit course which the students can avail out of their interest in research. The credits from this course will not form the part of the credit requirements to be fulfilled by the students to get their UG degree. So, most students would not register for this course. Sixteen students of 2006 ECE batch registered for this course during their eighth semester. As these students were all already carrying out research work as part of their project,

they all could easily get A / A+ grades. They were evaluated based on the research work features like innovation, significance findings, writing skills, presentation skills etc. Every month they presented their work in the class in the class room. Their research work was so impressive that four students were awarded A+ grades and remaining twelve students were awarded with A grades.

VII.   EVALUATION

All experiments have results and what we infer from the results gives a measure of failure or success of the experiment. As far as research is concerned there is no failure or success in the sense that even to conclude that particular results clarify that such a process or method or algorithm doesn't serve any purpose is valid. A questionnaire is given to 16 students of 2006 ECE batch and their response is evaluated. The details serve as a measure of the effectiveness of UG research. Eight students out of these 16 are currently doing their graduate program at various universities in USA and four student doing masters in India. Remaining four students are employed with IT companies at Bangalore / Cochin in India. Nine students responded.

TABLE III.   RESULT OF SURVEY

Questions	Response	
	Average	Standard Deviation
Research project was well defined	4.17	0.35
Enjoyed undergraduate research in ECE	4.72	0.44
Research experience was challenging	4.28	0.67
It met my expectation	4.39	0.70
It helped me learn relevant areas in ECE better	4.50	0.50
It helped me prepare for future course-work in ECE	4.67	0.71
It taught me how to solve problems in ECE	4.17	0.61
Research advisor was knowledgeable	4.87	0.33
Research advisor was accessible and helpful	4.83	0.35
Research advisor well managed the research	4.76	0.43
Applied knowledge from ECE courses taken before	4.44	0.88
Became exposed to new concepts	4.59	0.47
Developed analytical skills	4.20	0.64
Improved my writing skills	4.11	0.65
Improved my oral/presentation skills	4.06	0.73
Gained confidence in taking up new research projects	4.53	0.51
Was able to manage both research and academics	4.64	0.49
Gained confidence in my abilities to solve problems	4.53	0.51
Meeting the faculty on regular schedule was helpful	4.42	0.50

The questions are taken from [1] and modified for ECE department as shown in the Table III, previous page. All these students were in UG research for more than a year. They were asked to answer questions on learning, writing, skills developed, confidence etc. They were asked to rate on a scale of 1(Poor) to 5(Excellent). All the students who took part in the survey answered that they enjoyed UG research with a rating of 4.72. A significant observation is that the UG research work didn't interfere in their academics. The students gave a rating of 4.53 for the question related to this, with a standard deviation of 0.5. The following table summarized the survey questions and the response.

VIII. STUDENTS' BENIFITS

The following section describes in detail the benefits for the students in taking up UG research work.

A. Campus Selection

Multinational Companies such as Infosys, Cognizant Technological Solutions and Wipro VLSI come to conduct campus recruitment. Campus selection usually takes place in the fourth year of undergraduate studies. By this time, the students who have been working on research projects from the second year onwards will have in depth knowledge in subjects, strong fundamentals, good oral and communication skills, managerial skills and good problem solving skills. These skills help them a lot in actively participating in group discussions and face interview boards with great confidence during their campus selection. The students of ECE batch 2006 presented in the case study have got placed into the companies mentioned above.

B. Project Reviews

As in the case of any university across India, all students are expected to do a major project during the final semester of their undergraduate studies. Students who have been involved in research work since the second year will have gained all the required skills to progress to a greater level in implementing the project. Their projects will have a good number of features which will stand out from the rest of the lot. By this time, the students will have published about two to three international papers and will have enough research work to present to the reviewers.

C. Technical Papers

As the students spend more time in their research work, they will have enough research material with them to showcase at different national technical festivals and international conferences. The students often participate in paper presentation contests in technical festivals across the country and win various prizes. For instance, a group of students of ECE batch of 2006 have won more than five prizes in national technical festivals in various colleges across Kerala, India. Also the students are able to attend international conferences and discuss their work with the renowned professors, industrialists etc. They are able to get internship opportunities at companies or get to work at research labs at other universities because of these interactions. They are able

to visit the foreign universities, research facilities and the infrastructure. They get new ideas, solution to particular issues as they interact with various people in the research field.

D. Feedback

The following are some of the comments of the students who participated in the survey as given in the previous section.

".. The challenges faced, concepts and project management skills learnt during research have indeed helped me in quickly ramping up and working on projects in the industry."

"..I really enjoyed being a part of the group. The strong foundation helped me in my Masters."

"…The research helped me to learn new techniques and to find a solution for almost all the problems that one may encounter during a research. It also helped me to learn how to work in a team. Though I ended up in an IT company after my undergrad, the passion to do research which I gained from Amrita helped me to quit job and to pursue my Masters with research…"

"..The projects I did were in the fields of Processor Architecture, Embedded Systems and Image processing. These projects helped me to develop my knowledge in my subjects of interest and it also helped me during my graduate studies at University of Cincinnati..."

IX. TEACHERS' BENEFITS

In the process of guiding students in UG research, the teacher community also benefits a lot. The projects the students choose and the research work they carry out are in various technologies like VLSI, Embedded Systems, Robotics, Biomedical etc. to properly guide students with UG research work teachers are getting updated with recent research work, research trends, latest technological development etc. in the particular research area. They are referring to various published conference papers, journal papers of IEEE, ACM etc. In this process their knowledge also deepens and they are able to help students to their satisfaction. Particularly, the students dealt here are UG students who are still beginners in many aspects compared to graduate students. Teachers learn patience which is the foremost quality required in UG research. Guiding students at UG research level is in itself a great task. They learn to keep both the research and academics balanced. Above all it gives a satisfaction to teachers that they have shared their knowledge, skills etc. which made the students to achieve something great in their life.

X. CHALLENGES IN UNDERGRADUATE RESEARCH

A. Finding a Dedicated Group

The major challenge in UG research is finding a group of dedicated students who are motivated to carry out the research. In case of any Indian universities, a student is

supposed to register for more than 20 credits of theoretical course work per semester. Most of the time will be spent in academics and students want to spend remaining time is sports, games and extra-curricular activities. In such situation, most students don't care about starting any project work which is outside the curriculum and not going to fetch any credit. The group of students should have proper understanding within themselves. Students and advisors should also be in good terms.

B. Keeping Students Motivated

After finding a group of interested students, keeping them motivated is another big task. As they are undergrad students, they easily get frustrated. For example, after spending significant amount of time with the project, if they don't get expected results they don't want to continue further. They get dejected very quickly. At this point of time proper counseling about the outcome of the project results should be given to keep the students motivated. Also a student within a group might not be interested in continuing with the work because it not what he / she expected.

C. Devoting Dedicated Time

The students should be able to spend dedicated amount of time every day with a break during weekends, for satisfactory outcome. Many days student won't be able to work even for an hour due to academic load like submitting assignments, preparing for periodical tests, lab exams, sports etc. Because of this, it takes long time to come out with any significant findings in research work or to complete the project. Most of them tend to leave for their homes rather than stay and work during weekends.

D. Balancing between Academics and Research

Even though UG research groups are chosen from those students who voluntarily want to take part in this, many times questions are raised at department level if this is interfering with their academics. A proper balance should be maintained between academic work and research work. Students are too enthusiastic to spend more time on projects and research work than the required time. One or two students in a group spend their project or research hours in writing assignments, preparing for tests etc.

E. Student Fitness for Research

As the groups are chosen as early as second year, much of their technical background, understanding of basics is unknown. Sometimes the course work or lab work related to their project or research comes in future semesters. Also, a few students who join out of curiosity leave the group later because they just wanted to know what a research is or just wanted to fill up their resume.

XI. CONCLUSION

The feedback from students who participated in UG research, the students who are currently participating and getting benefit from this, the evaluation as shown in Section VI etc. all point to one fact that UG research is not a waste of time. As in any organization, here are there are challenges that the faculty and students both have to face. But that is also part of research work. The UG research work taken in ECE department has set a trend in the University that even UG students are capable of research work with publications in renowned digital library sites like IEEE, ACM etc. This has surpassed all the expectations and also the notion that research publications is only for Graduate or PhD students. Students learn how to choose a project, how to manage it, how to introduce a research module in it, how to work in a group etc. It enhances not only the technical understanding but also the managerial and creative aspect of the mind. It gives them the confidence and faith that even UG students can reach great heights with their research work. It helps them in facing challenges, apply the class room knowledge, develop analytical skill, develop writing skills, gain confidence etc.

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