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A Structured Approach to Honours Undergraduate Research Course, Evaluation Rubrics and Assessment

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Abstract This paper presents a new approach to the Honours Undergraduate Research Course design and implementation. The course design process, assessment and evaluation rubrics are provided. Lessons learned and the experience of the faced challenges and opportunities for two cohort offerings of the course during the winter terms of 2011 and 2012 are highlighted. Assessments show that major benefits include increasing interaction with the faculty and increasing intellectual maturity, skills, knowledge and confidence for the students and for the faculty, the furthering of research projects by the participation of undergraduate students. The course can serve as a model that can be easily adapted for use across the disciplines of science, technology, engineering and mathematics.

Keywords Honours Undergraduate Research · Course design · Undergraduate Research Program · Science, technology, Engineering and mathematics (STEM) · Evaluation rubrics

Introduction

Motivation and Context

Undoubtedly, undergraduate research is widely appreciated as a great educational activity for increasing student's research skills, providing increased opportunities for learning, encouraging professional relationships between faculty and students, and advancing the body of knowledge in the researcher's chosen field. Several universities in many countries and especially in the USA offer research programmes for undergraduate students. In addition, some large industries and government agencies also offer such programmes and on-site training.

In this paper, we would like to share our experience about the design of the undergraduate research course at King Fahd University of Petroleum and Minerals (KFUPM), Saudi Arabia. An Undergraduate Research Program Initiative (URPI) is suggested to offer upper-division undergraduate students with outstanding academic potential the opportunity to work closely with faculty mentors on research projects.

There are already several possibilities for involving undergraduate students in faculty research projects, using several available grant sources, for example, Internal and Fast Track of Deanship of Scientific Research, Research Institute, The National Saudi Funding Agency KACST (King Abdul-Aziz City of Science and Technology), etc. The availability of opportunities can be extended to all university academic departments and research centres. Many students elect to tackle special problems to gain valuable hands-on experience in the laboratory or computational settings with a faculty member. As a researcher, a student will seek answers to questions of great interest. He/she will choose the tools, gather and analyse the data that will help him/her to delve deeper to find answers. However, a more formal involvement of students through university administration will certainly increase the number of participating students and the quality of their research achievements. Furthermore, the programme will allow students to learn more and improve their ability of research, which will be linked to their performance in their graduate studies. They will receive support in exploring

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and planning for postgraduate programmes, particularly doctoral-level programmes, and possibly pursue an academic career in teaching and research. This initiative is also aimed at strengthening the relationship with the local industry, allowing students greater hands-on experience in real-life engineering problems and exposure to research challenges. Another objective of the programme is to enhance the multidisciplinary component of the students and, more generally, to prepare them for their professional careers, which may not necessarily be in research (NSF 2005; SEUGR-KFUPM 2011). The higher administration has shown a keen interest in the idea and provided strong support for the initiative.

The main contribution of this paper is that it provides a new structured and systematic approach to an Honours Undergraduate Research Course (HURC), as well as highlights lessons learned along with an assessment of the two first offerings. The course introduces undergraduate students to basic skills about conducting an independent research project. They learn effective methods for carrying out literature reviews and for discovering current research methodologies. They use appropriate research tools and search engines, define research topics, devise research questions, develop critical thinking, write computer code, model and simulate computational phenomena and conduct and analyse experiments. Each student interacts with his project-mates and with other project teams. He also interacts with a faculty instructor and a faculty supervisor. According to the best of the author's knowledge, the approach and structure of the undergraduate research experience course proposed here has not been published before. It constitutes a step forward in the contribution to undergraduate teaching by augmenting learning capabilities and enhancing multidisciplinary practices for building and improving the complex problem-solving abilities of the students.

Related Works

Many countries and universities are offering research programmes for undergraduate students. In the UK, it has been recognised as a national strategic priority for learning and teaching in higher education. We quote from the (HEFCE 2006/11 strategic plan) report "…ensuring that teaching is informed and enriched by research areas where institutions could seek to invest funds students experiencing research, and developing research skills" (UKHE 2012). There is significant variety in the design of the programmes and their functions, from summer association training (Murf Program at Caltech, SURF Program at Yale University) to thesis mode (Georgia Tech) and across multiple option and credit-based mode (URAP at MIT). Additionally, some large industries and government agencies offer such programmes and on-site training. A sample list is provided in (UKHE 2012; Andalon 2011; URP 2012; Boyd and Wesemann 2009; NASA 2012). In (Russell et al. 2007), the establishment of the benefits of research experiences for undergraduates in the sciences is provided based upon a three-year study, and first findings were very informative with respect to the benefits of undergraduate research experiences.

The U.S. Department of Education and National Science Foundation funded several research proposals into the importance of undergraduate research. (Please see DeHaan 2005; Seymour et al. 2004; Bauer and Bennett 2003 and the references therein).

In a study reported in (Seymour et al. 2004), undergraduates from 41 institutions participated in an online survey on the benefits of their undergraduate research experience. Participants indicated gains on 20 potential benefits and reported on career plans. Over 83 % of 1,135 participants began or continued to plan for postgraduate education in the sciences. In (Thiry and Laursen 2011), the authors discussed the importance of mentoring interactions between students and their research advisors and their role in shaping scientist identities of the UR apprentices through transmission of values, confidence, disciplinary knowledge and skills.

Undergraduate research experience has been shown to be effective in recruiting and retaining these populations of students within the disciplines of science, technology, engineering and mathematics (STEM), often leading to careers in research (Villarejo et al. 2008; Lauren et al. 2010).

Link to Curriculum Design

In this subsection, we briefly outline related works to undergraduate research and curriculum design in general and then follow-up specifically with undergraduate research courses.

The increasing theoretical content of engineering programmes in association with the lack of design and creativity has discouraged many future engineering students, and many universities have witnessed a decline in the number of engineering applicants. Several surveys have revealed that the alumni overwhelmingly state that their education would have been far more effective if they had had access to independent studies and research courses through which they could solve real-world problems and practical applications (Biggs 1999). Over the past two decades, several industrial companies, engineering educators and accreditation boards have raised the design issue in the engineering curriculum. The Accreditation Board for Engineering and Technology (ABET) reintroduced design and mandated minimum credits of design content in all the four-year undergraduate engineering programmes (ABET 2007a; ABET 2007b).

Learning through problem-based educational activities has been proven highly effective through the incorporation of related research activities into the curriculum or a particular course. The need to integrate faculty research with teaching at the undergraduate level was stressed in (HE-Academy 2012).

Introducing research for undergraduate students will also improve their skills in solving open-ended design problems, teamwork and communications, resulting in deep learning as stated in (Collier 1998; Schaefera and Panchalb 2009; Lapatto 2009; Bloom 1956).

One related course activity to the undergraduate research courses is the capstone design course. As defined in (Smith et al. 2005), a capstone course includes research, conceptual design process optimisation and examination of alternative processes, economic analysis and safety and environment considerations. However, while there is a strong similarity in terms of objectives between capstone and HURC, undergraduate research courses differ from senior capstone projects in more than one aspect.

First, HURC courses are research oriented, require substantial effort and can involve students who can start this track from junior or earlier levels. By their very nature, they are more student-centric. In contrast, generally, only senior students participate in the senior capstone project. Second, in contrast to senior design capstone, participation in the HURC should remain an option to undergraduates. Any effort to mandate it will probably cause resentment, and the basic objective of creativity may never be realised. Third, these two types of courses can be viewed as complementary and considered with an integrated approach. For instance, a senior student can first take an HURC course and then proceed to the capstone to devote more time for the realisation, prototyping and achievement of the project.

In the following section, "Design process and implementation" of the course are provided. The third section gives "Rubrics for students grading and evaluation". The fourth section introduces "Analysis of the experiment" from two offerings. The fifth section follows with "Course assessment" from two cohort offerings. The "Lessons learned and challenges" from the experiment and the challenges faced in improving for the next offerings are provided in the sixth section. Finally, the seventh section "concludes" the paper.

Design Process and Implementation

Introduction and Background

As mentioned earlier, undergraduate student involvement already exists in granted research projects at some faculties, but this participation is very limited in scope and number of students.

A second avenue into the implementation of undergraduate research experience was through six-week summer training by providing compensation-based activities to students and faculties involved in the programme. However, summer training was not viewed as the most practical approach considering that most of the students leave the campus during summer. Subsequently, it was thought that more students would be able to become involved in an undergraduate research course than in a typical one-on-one faculty–student situation. In addition, students engage in research by signing up for a class, and this may be easier for some students than approaching the faculty for research opportunities. The idea consists of a regular elective 3-credit hour special topics course for honours standing.

A significant search, benchmarking and analysis of several methods and course offerings on undergraduate research, together with consideration of the KFUPM context and environment specifics, have led us to the course format described hereafter. In the literature, there are published works on courses for undergraduate research (Smith et al. 2005; Balster et al. 2010). The work presented here is different from the ideas presented in those papers. In (Smith et al. 2005), an undergraduate research course was introduced and assessed through students' feedback on a first implementation. The course was open to all undergraduates with some requirements and most of the enrolment was from sophomores. The authors analysed the outcome of the course, but the paper does not include details of the course material delivery, and students learning assessment tools and rubrics. In (Mcnair 2012), the emphasis was put on research methods and literature review. The present work constitutes a step forward in the undergraduate research experience through a comprehensive and structured approach (Khoukhi 2011). The design process and implementation are outlined hereafter. For more details on the course material, syllabus, instruction delivery, learning objectives and expected outcomes as well as samples of students works, the reader is invited to visit the course website (available at https:\\seugr.ikfupm.com).

The course runs on a two-side basis; the first consists of regular lectures given by a faculty instructor who also is the coordinator and manager of the whole process. The second part is group based, where a student or a team of students work on a research project under the close supervision of a faculty member.

The course delivery starts with regular lectures (2×75 min) during the first four weeks, which involve an introduction to research, library and computer laboratory sessions. Blackboard contains the course reading material, lessons, handouts and corresponding PowerPoint presentations. The selected course reading material consists of chapters from some of the latest introductory research methodology textbooks, research journal articles and specialised research

training guidebooks. Students are required to access course material and post-assignments through WebCT.

During this period, the research projects will be introduced to the students. They will be presented with handouts to read, to develop an understanding of the foundations for their project, so that they can come up with a research proposal by the fourth week.

From the fifth week onwards, students will work hard on project tasks using appropriate methodology with respect to the timeline. During this period until week 14, one of the two weekly lectures will be devoted to a regular meeting of each project team with their faculty supervisor. The meeting time can be different from the actual lecture time arranged as convenient to the faculty and students. In this meeting, the team will consult with the faculty supervisor, provide him with a progress report, discuss any difficulties that they are facing, figure out solutions and receive guidance for subsequent steps. The faculty supervisor makes sure the student(s) are attending the weekly meetings. In the second lecture, each group will make a brief presentation to the whole class on the progress of their project. Two teams will present material at each class. In preparing for their presentation, the students will have the material well organised and connected in their own minds in order to communicate effectively their ideas to the others. The presentations will help the students prepare for speaking at conferences or giving a seminar.

During the final step (weeks 14 and 15), the students will organise their results into a finished product, concentrate on communicating their results by writing a short final report and a five to six page paper and prepare a conference presentation.

The course includes guest speakers; a series of two lectures will be delivered by international visiting scholars on undergraduate research experience at their respective universities.

Rubrics for Students Grading and Evaluation

Eight items comprise the grading; these components are given in the final evaluation form provided in "Appendix 1". Because of the dual nature of the course, research methodology and communication with a course instructor and a project with a faculty supervisor, the involvement of two faculty members for each student, or team of students, made it difficult and challenging to assess student learning, performance and grading. The complexity occurred mainly in trying to assess the learning attainment outcomes for each student or team of students based on non-traditional evaluation and grading components. Among the course components, the successful achievement of the project objectives is clearly a basic assessment of the technical work and a good demonstration of the student's level of understanding. However, other components, including project planning and research methodology skills, critical thinking and formulating research questions, data collection and analysis, interpersonal communication and team behaviours, are definitely important outcomes of the course.

For this reason, a set of rubrics were devised to assess each component of the grading policy through defined primary indicators for each activity (ATR 2012; Newell et al. 2002). In education jargon, the word *rubric* means "An assessment tool for communicating expectations of quality". From wikipedia.com (Wikipedia 2012), we quote: "A rubric is an attempt to communicate expectations of quality around a task. In many cases, rubrics are used to delineate consistent criteria for grading. A rubric can also provide a basis for self-evaluation, reflection, and peer review. It is aimed at accurate and fair assessment, fostering understanding, and indicating a way to proceed with subsequent learning/teaching" (STEM 2012; Woodin et al. 2009; CAS 2009; Wikipedia 2012).

The instructor and faculty supervisor will complete all rubrics as well as the final evaluation form for each student.

The defined rubrics are related to the grading components. Homework is based on multiple choices, true/false and related type of questions, which do not need a rubric for evaluation. In "Appendix 2", six rubrics are provided to evaluate the course grading components. In-class participation and meetings with supervisors (Rubric 1), team work (Rubric 2), the research proposal has two gradable parts: the proposal report and the proposal presentation which are assessed through Rubrics 3 and 4. Rubrics 3 and 4 were also adopted for the new undergraduate research grant initiated by the University Deanship of Scientific Research (DSR-KFUPM 2012). The achieved research is evaluated through the accomplishment of the projects. The research achievement component is given the highest weight through achieving objectives and deliverables as stated and claimed in the research proposal. The final report is assessed through rubric 5. The final presentation is assessed based on rubric 4 like for the proposal presentation, considering the progress made since the presentation of the proposal. Finally, regarding the conference paper, the faculty supervisor or instructor suggests a conference manuscript template according to the project topic. Rubric 6 provides with basic guidelines to assess paper writing abilities and performance.

Analysis of the Experiment

First Two Offerings

Two offerings of the course were provided. The first cohort was launched during the winter term of 2011, and the

second was during the winter of 2012. The student population was drawn from three majors; electrical engineering, industrial engineering and control and instrumentation systems engineering. A total of 22 students were enrolled during the two offerings. The faculty supervisors were from three departments: systems engineering, electrical engineering and mechanical engineering. A good number of faculty members with different areas of expertise provided projects ideas, and out of the fourteen project propositions, the following eleven projects were selected by the students:

1. Minimise tardiness in a single machine batch processing
2. Target reaching by avoiding obstacles for mobile robots
3. In-pipe leak detection based on pressure gradient
4. Rate of penetration prediction using extreme learning machines: a comparative study
5. Determination of crescent visibility regions on Earth
6. Model predictive control of reverse osmosis desalination plant
7. Consignment stock and VMI in a multi-buyer single-vendor supply chain: solution methods
8. Maze solver: an intelligent controller for mobile robots
9. Supply chain risk: critical infrastructure analysis
10. Improvement of the registration system at KFUPM
11. PVT properties prediction in reservoir fluid characterisation

Samples of Achieved Projects during the Course Offerings

Here, we provide with two sample projects, the first project was achieved during the first course offering, where as the second project was achieved during the second offering.

Sample Project 1. Tardiness Minimisation for Single Machine Batch Processing

This project is a research about minimising tardiness for single machine batch processing. It is a scheduling problem, which consists of minimising the tardiness of jobs assigned in batches to be processed by machines that have size and time limitations. This problem is common in manufacturing operations, such as heat treatment and wafer burn-in operations, and many problems can be created from the basic batch processing machine (Damodaran et al. 2007). The project aims to analyse the available techniques, propose better assumptions and reasonable conditions and then apply a suitable heuristic method to solve the problem.

Two students from the industrial systems engineering major took on this project. Initially, they had a very difficult time, but with the permanent support of the supervisor and instructor, they made their way and implemented a CPLX technique with General Algebraic Modelling System (GAMS) software (GAMS 2012). Then, they used Matlab (Mathworks 2012) and implemented a simulated annealing technique (SA) to arrive at an improved solution along with a comparative study. Ten experiments were performed by fixing the seed (random number generator) to generate the same random number for both CPLEX and SA with the same conditions (i.e. same number of jobs, batches and capacities) to compare the results. The experiments were performed with 10 jobs, 4 batches and a capacity of 5. Figure 1 compares the results of both CPLEX and SA in terms of the number of tardy jobs that they could produce. Then, more scenarios were generated to observe the performance of each approach as the size of the problem increases. It was noticed that the improvement of SA is significant compared to CPLEX, but the time needed to solve each scenario for CPLEX was clearly less. The students achieved a conference paper by the end of the term (Al-Salamah et al. 2012).

Sample Project 2. Rate of Penetration Prediction Using Extreme Learning Machines: A Comparative Study

Currently, a very important aspect of oil drilling projects is cost efficiency. One of the major concerns in the drilling industry is the knowledge of the rate of penetration (ROP). A prediction procedure ultimately aims to optimise drilling parameters resulting in a maximum ROP and minimum drilling cost. Several researchers have tackled the problem and many methods were proposed for the prediction of ROP. Many parameters have been considered using mathematical models and simulators. Motahhari et al. (2009) found by simulation that the weight on bit (WOB) is the most significant factor affecting ROP. The simulation input was the sonically generated strength log for a 5,790 ft interval. They simulated ROP results for different combinations of WOB and revolutions per minute (RPM). Eren (2010) predicted the ROP from actual field data using a

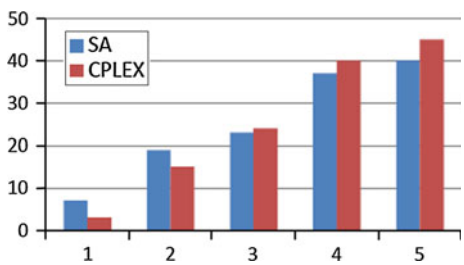

Fig. 1 Number of tardy job for both SA and CPLEX

multiple regression model. Computer networks using data piping collected the data, and at each data point, the ROP equation was optimised.

Another data processing procedure is artificial neural networks (ANNs). ANNs learn from the collection of previous data and through analysing the input/output relationships. Moran et al. (2010) built a Monte Carlo simulation for the data obtained by ANN for more analysis. Then, they used a six neuron ANN to obtain accurate ROP prediction. The results are used to rebuild the model and the cycle continues. Yashodhan et al. (2011) used data to optimise ROP and found that US$150,000 could be saved.

In this project, the use of extreme learning machines (ELMs) paradigm is proposed. ELM is an artificial intelligence technique that is a feed forward learning algorithm for single-layer neural networks (Huang 2010). It is known to be very fast and accurate compared with other types of ANNs.

A student of junior standing from industrial systems engineering took this project and delved into it. The course instructor provided a couple of lectures on computational intelligence techniques because in this very special offering of the course, all student projects required various computational intelligence techniques.

The main difficulty faced in implementing this project was that of data collection. Most drilling data are commercial and thus confidential. Initially, the work was begun using published data by (Bourgoyne and Young 1974). The student made an extensive search with the help of the supervisor and eventually collected two other significant data sets to perform the study and achieved substantial conclusions. However, in order to provide a fair comparison of different prediction models, including multi-regression models, the input data chosen were the same as in Eren's (2010) study. Seven drilling input parameters were used: depth, bit weight, rotary speed, tooth wear, Reynolds number function, ECD and pore gradient. The rate of penetration is the output. The comparison criteria are based on the time and accuracy of the training and testing stages.

The student achieved a thorough study by implementing ELM and a radial basis functional network (RBF) with various activation functions, seeking higher prediction accuracy. The results achieved by the student were excellent significantly outperforming regression models. A sample of the results is shown in Fig. 2. Three conference papers were achieved from this project, of which two already published (Al-Arfaj and Khoukhi 2012; Khoukhi and Al-Arfaj 2012) and a journal paper is being finalised. As another outcome, the student is to start his senior design project on the same research topic, benefitting there from gained knowledge and experience on subject matter from the course.

Student Grades and Publication Outcomes

By the end of the course, many students had delivered on time and had done a great job!! We recorded two projects as having an incomplete grade (IC) for each cohort, but all other students finished their projects with grades ranging from B+ to A+. In addition, five conference papers have already been published, of which two journal extensions are under finalisation and two other conference papers have been submitted. Furthermore, seven students applied for postgraduate programmes, among which four are already enrolled.

Course Assessment

Students Feedback

Mid-term Feedback

Mid-term student feedback and a qualitative assessment were conducted by an independent instructor in two steps. The first step was through individual answers to the survey questions below. Then, all students' answers were discussed, and a class agreement was established, as follows (the provided answers correspond to the second course offering):

1. What do you like most in this course?
   - Something new that trains us to become a researcher
   - Initiates us in publishing and gives us the opportunity to contribute to knowledge (conference papers)
   - Enhances our motivation for postgraduate studies
2. What do you like least in this course?
   - Some projects were not set and needed reworking
   - The course has no textbook
3. What do you suggest as specific changes?
   - A two-semester (or 1 semester + 1 summer) course would be more appropriate to cover the material in more details
   - Increase enrolment and have students from multiple majors

End of Term Feedback

To assess student satisfaction and learning outcomes, the students enrolled in the course completed a (pre) survey given at the first class of the semester and another (post))

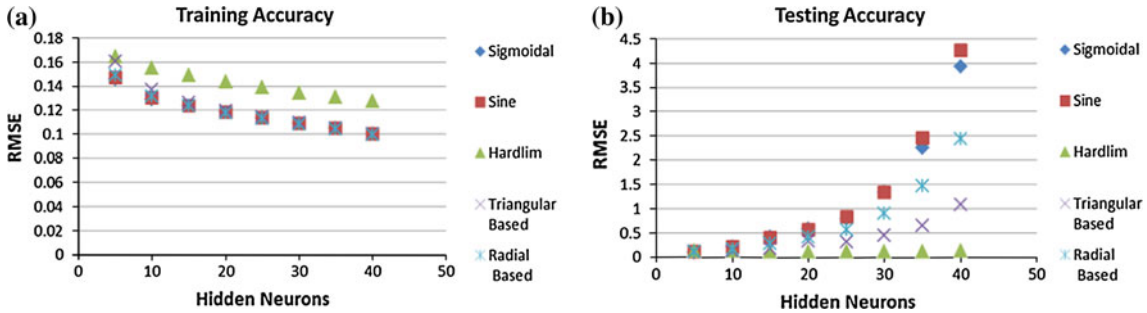

Fig. 2 Accuracy versus no. of hidden neurons (5–50) for various activation functions. **a** Training accuracy, **b** testing accuracy

survey at the end. The surveys and assessment instruments of the Howard Hughes Medical Institute (SURE 2012) were modified and customised to evaluate the proposed undergraduate research experience course. In this assessment, students commented on a checklist of possible benefits derived from the course. They were asked to rank their confidence, skills and knowledge as a researcher. The questions and students' answers are provided in Figs. 3, 4 and 5 below. The survey's tests include 24 questions pertaining to confidence, 15 questions pertaining to skills and 11 questions pertaining to knowledge. Figure 3 displays the student's answers on the questions linked to their increase in confidence to do research. The students were asked to rank their confidence on a scale of 1 (worst) to 5 (best). The answers show clearly the significant confidence the students gained upon completing the course.

Figure 4 displays the student's answers on the questions linked to their increase in skills to do research. Again, the students were asked to rank their skills on a scale of 1 (worst) to 5 (best). The answers show clearly the significant skills the students gained upon completing the course.

Furthermore, in order to determine the impact of taking the course on the students, after two offerings we followed up with a post-survey. Among the respondents, nine students completed their degrees, six graduated and went to industry and three pursued graduate programmes, of which two were enrolled in North American universities.

Five students were doing their capstone design projects after taking the course. Figure 5 displays the students' answers to 11 questions on how successful their experience was in relation to their current work and studies. Again, the students were asked to rank their confidence on a scale of very helpful to not helpful. The answers show clearly the significant benefits the students gained upon completing the course.

Faculty Participants Feedback

Last but not least, faculty participants were also surveyed. They were very cooperative and highly appreciative of the experience. They found the course to be a good way to enhance research abilities of undergraduate students by working closely to faculty members and graduate students. Suggestions for the next offerings of the course were as follows:

- They highlighted the necessity of planning to ensure proper budgeting for the course. Some students had to purchase some small items at their own expanses.
- Some faculty members expressed their wishes to have higher and multi-major enrolment because of the nature of the projects.
- Some faculty members suggested linking the course with the capstone design project. Others suggested offering the course over two consecutive terms. In the first term, the students will receive a thorough preparation in research and use of tools (introduction to research, problem definition, literature review, research proposal writing and presentation). In the second term, the students implement what they have studied and gathered during the first term on a specific research project. This proposal is being studied, and ways of merging the undergraduate research course and the capstone project are being considered for future course offerings.

Faculty participants were asked to rate the course components based on a customised questionnaire from SURE tools. The survey was related to the emphasis given to some aspects of the course during their participation. The twenty-nine questions were linked to different features of the course, especially the students, projects, course material and instruction delivery, proposal and final presentation attendance by the faculty supervisors. The answers show clearly the faculty's satisfaction and the significant skills the students gained upon completing the course. Figure 6 displays faculty participants' feedback.

Lessons Learned and Challenges

Several challenges had to be faced: from proposing projects able to be carried out within a 10-week period, getting the

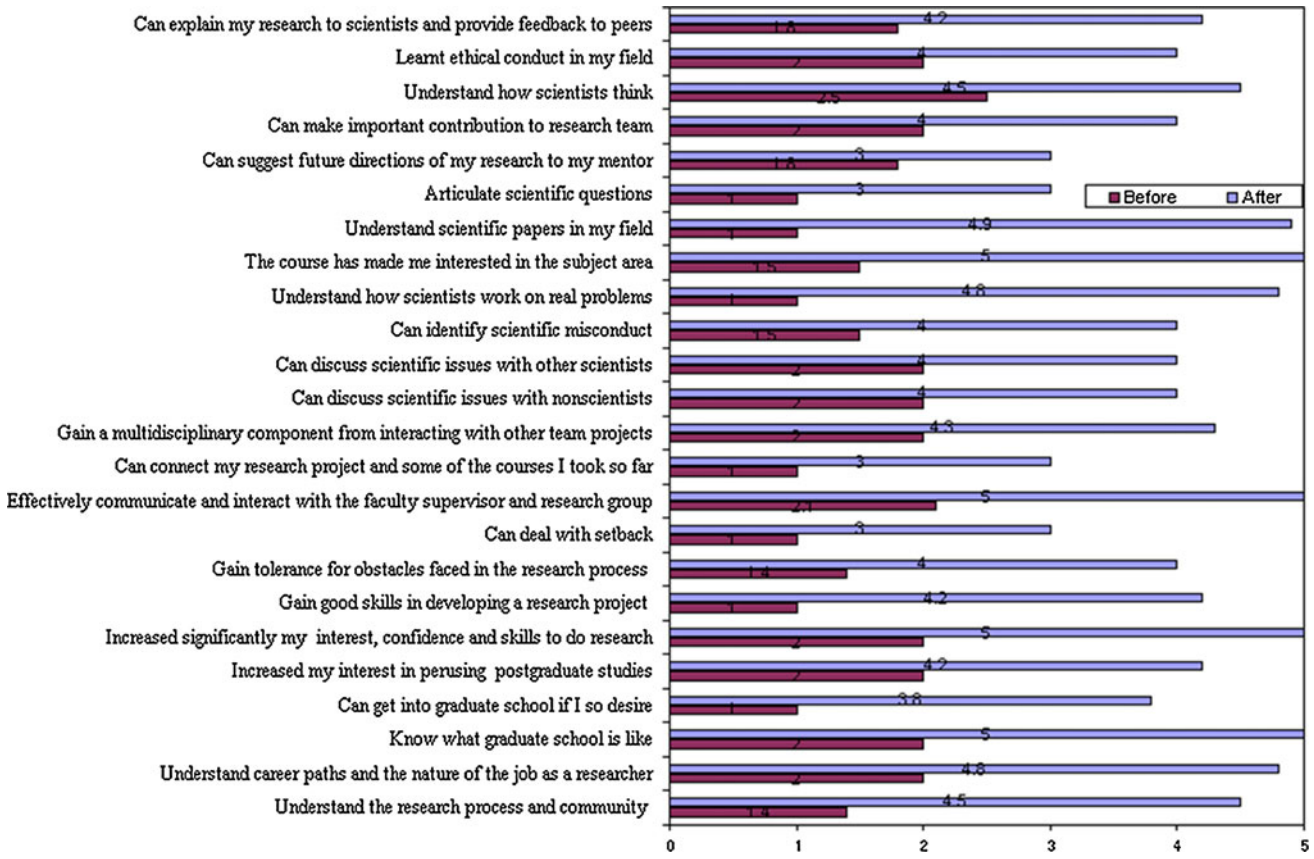

Fig. 3 Students' self-evaluation on questions linked to their increased confidence to do research

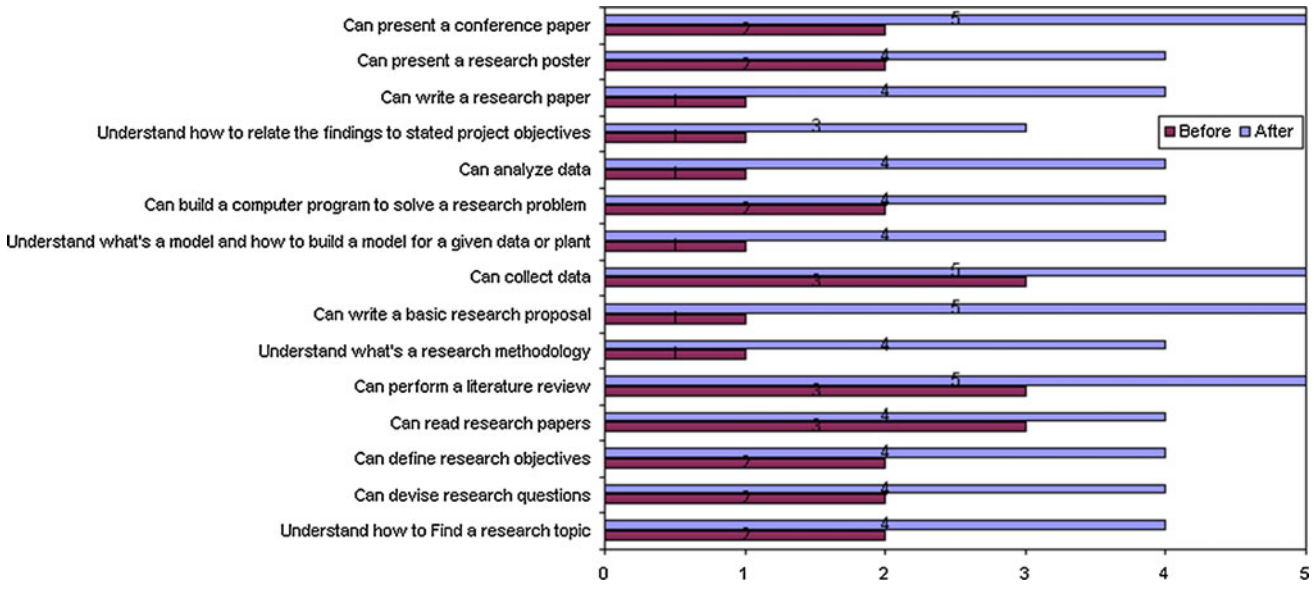

Fig. 4 Students' self-rating on 15 questions linked and increased skills to do research

right student or team for a given project, helping students that might be stuck on a certain question and leading them in on, to maintaining general interest and enthusiasm for the faculty participants. The typical lessons learned are:

Regarding the Students

Probably, the most important lesson is that every student holds an amazing and unlimited potential that may be

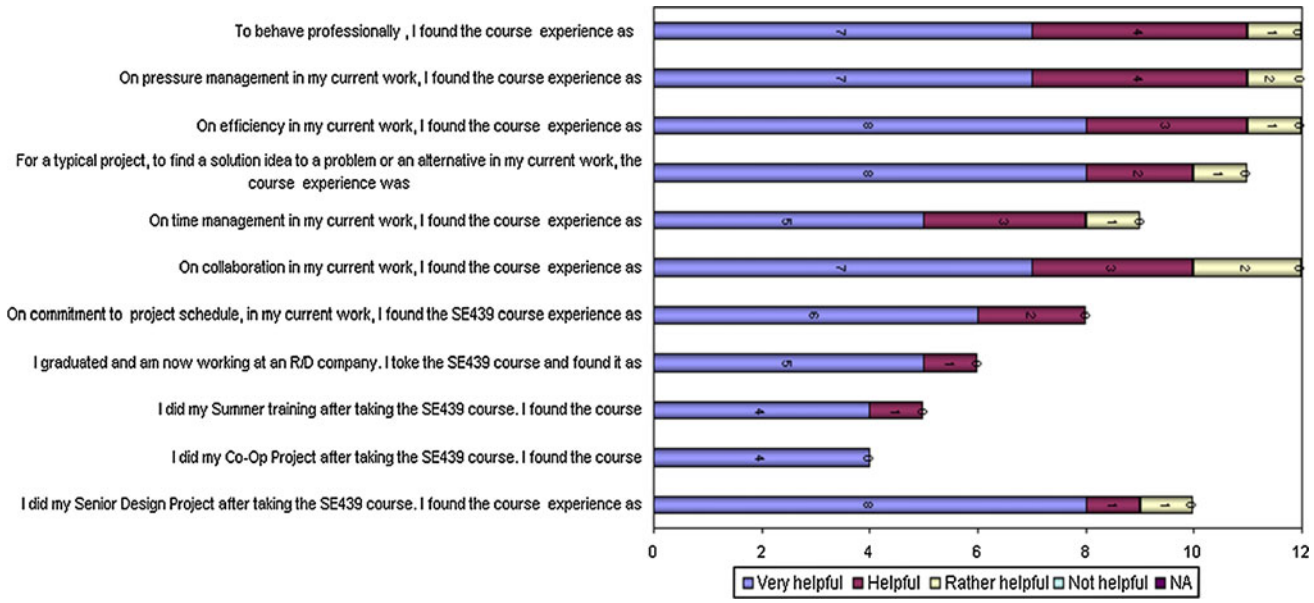

Fig. 5 Students' feedback on how successful their experience was for their current work and studies

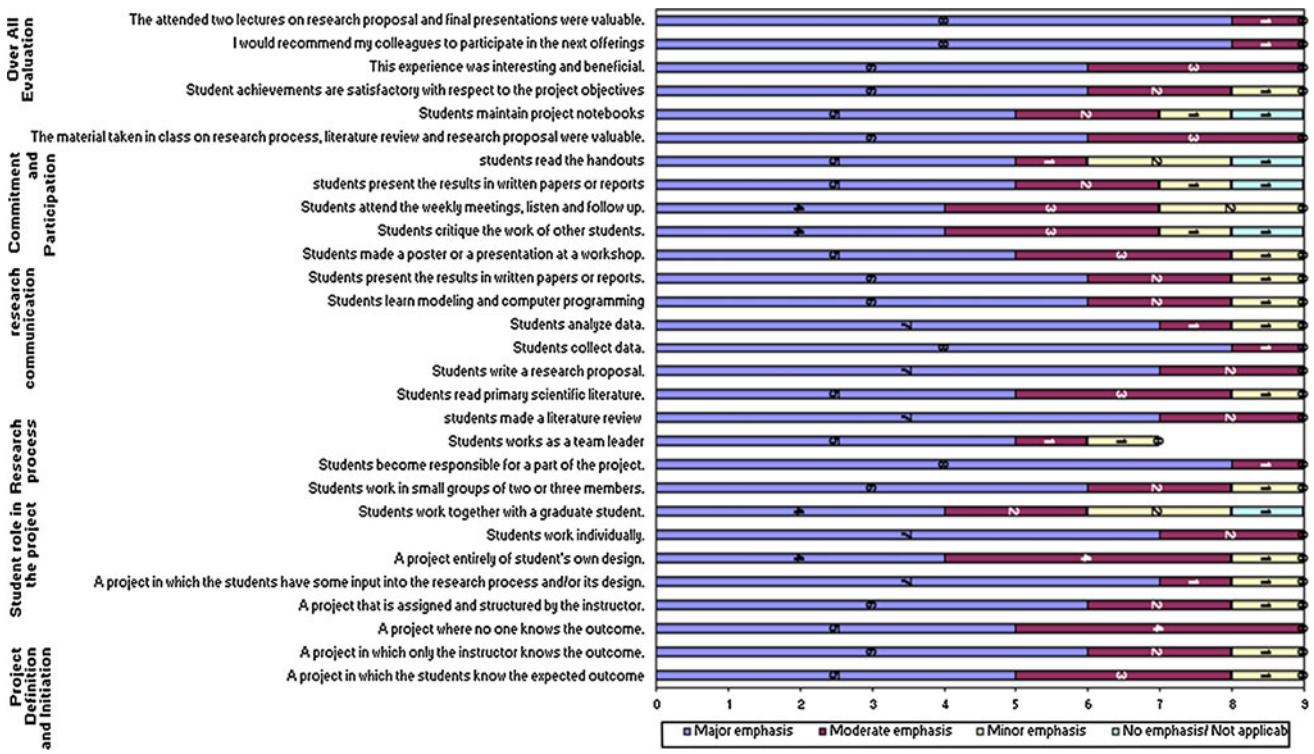

Fig. 6 Faculty participant feedback on different features of the course

manifested through undertaking high-quality research, regardless of his/her conventional grades in the traditional courses. I learned the value of enthusiasm, sincere motivation and superior commitment when the advisor demonstrates his/her genuine belief in the students' capabilities and expresses his/her gratitude to them for the value of their work and for the opportunity to collaborate.

Regarding the Faculty Supervisors

To foster the depth of learning, the advisor is encouraged to address the major issues independently. This may take time and frustrate the advisee, but the advisor must be patient, only intervenes just prior to the critical moment and never let the advisee cross the threshold.

Furthermore, the regular meetings once or twice a week are vital for the success of the project. The advisees often have minor questions, which if left unanswered may cause frustration and stall progress, whereas quick clarification may require only modest effort and permit the advisees to progress faster.

Regarding the Projects

The projects went through several reformulations and iterations. To achieve high-quality research, the research project must be designed so that it can be completed within a time frame of 9–10 weeks by a student or a team of students; each with roles and tasks well defined and spelled out. One way to do that is to design scalable research problems to fit students' skills and interests. Doing this, the assessment and evaluation of the students will be possible with the least subjectivity. Furthermore, the allocation of well-defined responsibilities for each student, allowing them to work within a team, will induce in them a qualitatively high level of commitment to succeed.

On the other hand, because of the multidisciplinary nature of the course and suggested projects, it is thought to generalise the offering at the university level from both science and engineering departments.

Conclusions

In this paper, we presented a structured and systematic approach for undergraduate research course design and implementation, as well as student evaluation rubrics and a prime course assessment from two offerings. The course takes into account context and environment specifics and can serve as a model easily adaptable for use across the disciplines of science, technology, engineering and mathematics (STEM). The paper presented several features and challenges that need a constant struggle to overcome and improve. We believe that undergraduate research experience will not only allow students hand-on practice in real-life engineering problems but will also enhance their learning and understanding of many challenging issues related to their majors.

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Appendix 1: HURC Final Evaluation Form

Term: _____ Date: _____
Student name: _____
ID Number: _____
Project title: _____
Faculty supervisor: _____
Faculty instructor: _____

Grade components	Instructor	Supervisor	Total
Homework	10	0	10
In-class participation/meetings with supervisor	5	5	10
Team work	5	5	10
Proposal report	5	5	10
Proposal presentation	5	5	10
Final report	10	20	30
Final presentation	5	5	10
Paper writing	5	5	10
Total	50	50	100

Earned letter grade:

A+	A	B+	B	C+	C	D+	D	F
95–100	90–94.9	85–89.9	80–84.9	75–79.9	70–74.9	65–69.9	60–64.9	00–59.9

Justification in case of an "IC" grade:

_____
_____
_____
_____

Signatures:
Instructor: _____
Date: _____
Supervisor: _____
Date: _____

Appendix 2: Assessment Rubrics

Rubric 1 In-class participation/meetings with the supervisor

Student name: _____
ID Number: _____
Project title: _____
Faculty supervisor: _____
Faculty instructor: _____

Performance indicator	Exemplary 4-3	Satisfactory 3-2	Developing 2-1	Unacceptable 1-0	Score	Weight	Total Score
To fill by instructor							
Attendance/ promptness	Student is **always prompt** and regularly attends classes.	Student is **late** to class **rarely** and **regularly attends** classes.	Student is **late** to class **once** every two weeks.	Student is late to class **more than once a week** and/ or has **poor attendance**.		X1	
Level of engagement in class	Student **proactively contributes** to class by offering ideas and asking questions **more than once** per class.	Student **proactively contributes to class** by offering ideas and asking questions **once** per class.	Student contributes to class by offering ideas and **asking questions once** per 2 or 3 class.	Student **rarely or never** contributes to class by offering ideas and asking questions.		X1, 5	
Preparation	Student is **always** prepared for class with assignments and required class materials.	Student is **usually prepared** for class with assignments and required class materials.	Student is **sometimes prepared** for class with assignments and required class materials.	Student is **rarely** or **almost never** prepared for class with assignments and required class materials.		X1, 5	
To fill by supervisor							
Commitment in meeting with the supervisor	Student **always attends and prepares** for the meetings. He asks **interesting questions** developing good prospects for project achievement.	Student **always attends the meetings** and has good participation.	Student **missed** (2) meetings. He participates only **a little** in the meetings.	Student has **4 or more absences**. He neither prepares nor participates.		X2	
Technical awareness and comprehension	Clearly **demonstrates an awareness of the related works** and an **understanding** of information from **multiple literature** sources.	Shows understanding of the work in the field but has **limited depth and breadth**.	**Knowledge is limited** to faculty provided materials.	**Fails to demonstrate** an awareness of the works of others and the significance of their project.		X1, 5	
				Total			
				Supervisor total/5			
				Instructor total/5			

Grand total:
Comments and recommendation:

Rubric 2 Team work

Student name: _____
ID Number: _____
Project title: _____
Faculty supervisor: _____
Faculty instructor: _____

Performance indicator	Exemplary 4-3	Satisfactory 3-2	Developing 2-1	Unacceptable 1-0	Score	Weight	Total Score
For each student							
Research and information gathering	**Collects a great** deal of information—all relates to the topic	Collects **some basic information**—most relates to the topic	Collects **very little** information—some relates to the topic	**Does not collect** any information that relates to the topic		X1	
Fulfilment of role in team duties	**Performs all duties** of assigned team role	Performs **nearly** all duties	Performs **very few** duties	**Does not perform** any duties of team role		X1	
Contribution to defining/ achieving project objectives	**Excellent contribution in** defining/achieving objectives that thoroughly address fundamental project needs	**Acceptable contribution in** defining/achieving objectives	**Makes some contributions** in defining/achieving objectives	**Takes little initiative** in defining/ achieving objectives		X2	
Leadership	Leadership role is **assumed by** the student for his own tasks and sometimes **helps other** team members and initiates new ideas	Leadership role assumed by the student for tasks is **apparent** but **rarely takes initiative** to help other team members.	The contribution of the student team member is limited and **not well identified**	The efforts are very **scattered**. **No** leadership		X2	
For each team							
Share equally	**Workload** and variety on each member is **fair** and shared **equally**	**Workload** and variety on each member **seems fair**	**Workload** and variety on each member **seems unbalanced**	**Workload** and variety on each member is **completely unbalanced**		X1.5	
Project plan execution	The team **effectively and safely executes** the project plan; **making significant progress** and modifying the plan as necessary	The team **executes the project** plan but has **difficulty** over coming setbacks	The team **partially executes the project** plan and needs thorough help from the supervisor and/or instructor	The team works **haphazardly** with little chance of achieving project objectives		X1	
Project organisation/ timeliness	**Effectively organises** project tasks to minimise wasted time and effort	**Identifies relevant** tasks but may struggle with setting priorities	**Partially identifies relevant** tasks and has difficulty in setting priorities	**Not organised**		X1.5	

Performance indicator	Exemplary 4-3	Satisfactory 3-2	Developing 2-1	Unacceptable 1-0	Score	Weight	Total Score
Keep detailed records	The **team keeps detailed records easily** followed by others. These **records include** a laboratory notebook, and purchase records and minutes of meetings **are always** recorded	The team **keeps a laboratory notebook** but records **lack organisation** and details of the contribution made by each team member. All minutes of meetings are recorded	The team **keeps a laboratory notebook** but **records contain omissions.** Minutes of meetings are sometimes recorded	The team **keeps poor, sketchy** or no records and details of **contribution** made by each team member are **not identified**		X1	
				Total			
				Supervisor total/5			
				Instructor total/5			

Grand total:

Comments and recommendation:

Rubric 3 HURC Research Proposal Report

Student name: _____
ID Number: _____
Project title: _____
Faculty supervisor: _____
Faculty instructor: _____

Performance indicator	Exemplary 4-5	Satisfactory 3-4	Developing 2-3	Unacceptable 0-1	Score	Weight	Total score
Introductory matters, title, abstract and cover page	Cover page, title and abstract are **informative, succinct** and offer **sufficiently specific details** about the problem issue and proposed methods of the study	Cover page, title and abstract are **relevant**, offering details about the proposed research study	Cover page, title or abstract **lack relevance** or fail to offer appropriate details about the problem issue of the proposed study	Cover page, title or **abstract are missing or inappropriate** to the given problem, research questions and method		X1	
Introduction to problem. Significance and purpose of the study	Presents a **significant research** problem. Articulates **clear, reasonable research questions** given the purpose and methods of the proposed project. The statements are **clearly supported** from the literature	Identifies a **relevant research** problem. Research questions are well **stated and supported** by and connected to the established literature	Problem identified but the statement is **too broad** and the description **fails to establish** the importance of the problem area. The research questions **are ambiguous**. Connections to the literature are **unclear or** questionable	Statement of the problem, significance, purpose and questions/ hypotheses **omitted or inappropriate**		X1.5	
Literature review	**Narrative integrates critical** and logical details from the peer-reviewed literature. **Each key question is grounded** to the **reliable** literature	Project's key questions are **connected to relevant literature**	Selected literature is **not from reliable** or up-to-date sources. Literary **support is vague or ambiguous**	The review of the literature is **missing, irrelevant, or inappropriate**		X1	
Research objectives	The purpose, questions and **objectives are mutually supportive and coherent.** Appropriate specific objectives have been **clearly** stated	The objectives are described **but with insufficient details**. Specific objectives are **defined** but some of them **not clear**	The research objectives are **confusing or incomplete** given the research questions and problem statement	The research objectives are **not understandable or are not** identified		X 1.5	
Methods and procedures	Procedures are thorough, **manageable and coherent; powerful for generating valid and reliable data. Clear strategies** are presented to achieve research objectives	Procedures for project **implementation and problem solving are identified and** described in a chronological fashion	Procedures for data gathering, model building and problem solving are **incomplete or lack relevance** to purpose and to research questions	Procedures for gathering data, building models and solving the problem are **omitted.**		X 1.5	
Expected outcomes	Outcomes **clearly exceed** what is expected from the project	Outcomes **probably conform** to what is expected from the project	**There is a good chance that the** outcomes **do not conform** to what is expected from the project	Outcomes **clearly do not conform** to what is expected from the project		X 1	
				Total			
				Supervisor total/5			
				Instructor total/5			

Grand total:
Comments and recommendation:

Rubric 4 HURC Research Proposal Presentation

Student name: _____
ID Number: _____
Project title: _____
Faculty supervisor: _____
Faculty instructor: _____

Performance indicator	Exemplary 4-3	Satisfactory 3-2	Developing 2-1	Unacceptable 1-0	Score	Weight	Total score
Organisation/ opening	Has a **clear opening** statement that catches audience's interest; **maintains focus** throughout; summarises main points	Has opening statement **relevant** to topic and gives outline of speech; is **mostly organised**; provides adequate "road map" for the listener	Has opening statement that is **not very clear, partly** organised can improve.	Has **no opening statement** or has an **irrelevant** statement; gives listener **no focus** or outline of the presentation		X 2	
Content	Demonstrates **substance and depth**; **shows mastery** of material	**Covers the topic;** uses appropriate sources; shows **good understanding** of the material components	Only **partially** covers the topic/**does not master** a good number of the material components	Does **not give adequate coverage** of topic; **lacks** of **sources**		X 1	
Quality of conclusion	Delivers a conclusion that **is well documented and persuasive**	Summarises presentation's main points; **draws conclusions** based upon these points	**Some important** ideas are shown, draws **some conclusions;** he can provide better	Has **missing** or **poor** conclusion; **not tied to analysis**; **does not summarise** points that support the conclusion		X1.5	
Delivery (voice, body position and eye contact)	Has **natural delivery**; modulates voice; fluent, excellent pace, projects **enthusiasm, interest and confidence**; always faces audience and good eye contact	Has **appropriate pace**; has **no distracting mannerisms**; easily **understood**	Appearance **not very appropriate** has **some distracting mannerisms**. **Faces the screen** most the time**. Not enough** eye contact	Is often **hard to understand**; **lacks** enthusiasm, has a pace that is **too fast** or **too slow; too soft** or **too loud,** demonstrates one or more **distracting mannerisms**		X1	
Use of media	Uses **slides effortlessly** to enhance presentation; has an **effective presentation** without media	**Looks at slides to keep on track**; uses an **appropriate** number of slides	**More slides** than needed are shown/ **useless slides** than allowed and **did not cover** some parts of the material	**Relies heavily** on slides and notes; uses slides with **too much text;** uses too **many/ very few** slides		X1,5	
Timing	Started and finished **exactly** on time	Started and/or finished **a little bit** (2 min) late	**Moderate deviation** from targeted time (5 min).	Started and/or finished **fairly late**		X1,5	
Answers to questions	Demonstrates **full knowledge of topic**; explains and **elaborates** on all questions	Shows ease in **answering questions** but **do not elaborate enough**	**Answers most of the questions** but for some **needs** more practice	Demonstrates **little grasp of information;** has **undeveloped** or **unclear** answers to questions		X1.5	
				Total			
				Supervisor total/5			
				Instructor total/5			

Grand total:
Comments and recommendation:

Rubric 5 HURC Final Report

Student name: _____
ID Number: _____
Project title: _____
Faculty supervisor: _____
Faculty instructor: _____

Performance indicator	Exemplary 4-3	Satisfactory 3-2	Developing 2-1	Unacceptable 1-0	Score	Weight	Total score
Title, abstract and cover page	Cover page, title and abstract are **succinct**, **informative** and offer sufficiently specific details about the problem, proposed methods and generated data	Cover page, title and abstract are **relevant**, offering details about the proposed research study	Cover page, title and abstract **need improvement;** not very informative	Cover page, title or **abstract missing** or **inappropriate** to the given problem, methods used and data generated		X1.5	
Introduction section, significance and purpose of the study	**Excellent introduction**. Articulates reasonable, clear research questions given the purpose. The statements are **clearly supported** from the findings and state-of-the-art-literature	Has a good introduction; the **research** questions are **well stated;** and the findings are well introduced	**Little description** of the problem; the findings are only **partial** and/or **not well** introduced	Introduction to the problem, research questions and/or findings are **omitted or inappropriate**		X1.5	
Literature review	The literature review is **comprehensive** from the peer-reviewed research literature. The problem is **appropriately grounded** to literature. Project questions are **connected to the relevant**, **reliable** literature	The literature review is **appropriate** but needs to show advantages and limitations of other works	Review of the literature is **covered only partially**. It has **old** and/or **unreliable** references	The review of the literature is **missing** or **inappropriate** or consisted of **non-research-**based articles		X1.5	
Obtained results	Obtains **meaningful** results with **minimal** wasted **effort**	Produces **some results** but not enough (or too many)	Obtains **few meaningful** results but can improve	**Generates no meaningful** results		X2	
	Provides thorough **logical and correct analysis** of the data and discusses **critically** the findings	Provides **analysis** quite **sufficiently** thorough	Provides analysis but only **partially correct**	Little meaningful analysis or **deliberately incorrect;** findings **not** explained		X2	
Research objectives achievements	All Project objectives are **achieved;** and the results are **exceptional.**	Major objectives are achieved; **some are still developing;** and the results are **satisfactory**	**Some** objectives are **not completely** achieved; some results **need improvement**	Major research objectives are **not achieved;** the results are **not satisfactory**		X5	
Formulated conclusions	Formulates and **adequately supports meaningful** conclusions	**Needs some help** in formulating meaningful conclusions	Conclusions are **partially meaningful** and **incomplete**	Conclusions are **absent, wrong, trivial** or **unproven**		X1.5	

Performance indicator	Exemplary 4-3	Satisfactory 3-2	Developing 2-1	Unacceptable 1-0	Score	Weight	Total score
Recommendations for future work	Makes **insightful recommendations** and **succinctly addresses perspectives** for further research	Makes some **good recommendations** and perspectives for further research	Makes **broad** or **obvious** suggestions for future work	Makes **no plausible** suggestions for future work		X1	
English composition and citations	Consistently **well written; spelling, citations, references**, headings, table of contents, page numbers and document sections	Manuscript **conforms to most standards** of English composition	Manuscript contains **many mistakes and bad use of tenses**. Citations are **not appropriate**	Manuscript contains too **many mistakes Fails** to apply citations, references **not appropriate**		X1.5	
References	The references are **appropriate** for the statements; they are **up-to-date.** They are properly **cited following** the guidelines	The references are **appropriate** but are **not up-to-date and/or** are **not cited following** the guidelines	References are **not supporting** the study; cited in an ad-hoc way (e.g. [1–10], not **properly following** the guidelines	Most of the references are **not related** to the problem, **not up-to-date** and/or not **cited following** the guidelines		X1.5	
Mechanics and documents	**Is free or almost free of errors** of grammar, spelling and writing mechanics	Has **errors but they do not represent** a major distraction	Has **lots of errors** and **needs a major effort** of improvement	Has **many errors that obscure meaning**; **neglects important** sources or uses too few		X1	
				Total			
				Supervisor total/20			
				Instructor total/10			

Grand total:

Comments and recommendation:

Rubric 6 HURC Conference Paper

Student name: _____
ID Number: _____
Project title: _____
Faculty supervisor: _____
Faculty instructor: _____

Performance indicator	Exemplary 4-3	Satisfactory 3-2	Developing 2-1	Unacceptable 1-0	Score	Weight	Total
General comments/ Organisation/ Importance of the contribution	The paper is **clearly written** and **well organised**; the study is **original** and an **important contribution**. All parts and illustrations of the paper are **succinctly presented**	The writing **quality** and the **originality** of the contribution are **acceptable.** Has some **errors but they do not represent a major** distraction	The **originality** of the contribution is **not highlighted.** Has **lots of errors** Some parts and/or illustrations are **unnecessary**	The contribution is **not original.** The **writing** quality **is not acceptable.** Has **many errors that obscure meaning**		X2	
Title	The title **accurately describes** the paper content	The title describes **appropriately** the paper content	Title **describes only partially** the paper content	Title is **missing or inappropriate**		X1.5	
Abstract	The abstract is **succinct and informative enough** that it can stand alone as an **accurate summary** of the research. The abstract's **conclusions are supported by the results**	Abstract is **relevant**, offering **good details** about the research work	Abstract is **not very informative**, **needs improvement**	Abstract **is missing or inappropriate** to the research work		X1.5	
Introduction significance and purpose of the study	**Excellent introduction** states the **purpose** of the paper with a **solid rational** for it. The paper significance is **explained.** Articulates reasonable, **clear research questions** given the purpose	Has a **good** introduction; the research questions are **stated** and the **findings are introduced appropriately**	**Little description** of the problem; the findings are only **partial** and/ or **not well** introduced	Introduction to the problem, research questions and findings are **omitted or inappropriate**		X1.5	
Methods	The used **methods and assumptions are justified** and discussed as well their **validity**, advantages and limitations. The **errors** in using these methods are **reported and discussed**	Used **methods are justified** but their **validity**, advantages and limitations are **partially reported**	Used **methods** and their **validity**, advantages and limitations are **not appropriately justified**	Used **methods** and their **validity**, advantages and limitations are **omitted or inappropriate**		X1.5	
Data and results	D**ata accuracy and presentation are** displayed in the **clearest way** and the **findings are related to prior work** from the literature	D**ata accuracy and presentation are satisfactory**, **appropriate** link to prior works from literature	**Data presentation accuracy** is **not clear** some Figures need improvement	Data is **inaccurate** many Figure/ Tables **not understandable**		X2	

Performance indicator	Exemplary 4-3	Satisfactory 3-2	Developing 2-1	Unacceptable 1-0	Score	Weight	Total
Interpretation and discussions	Provides **logical, critical and correct analysis** of the data and discusses the findings. **Clearly explains** how the study supports or disagrees with previous studies and why	Provides **logical and correct analysis** of the data and discusses the findings, but do not **explains** how these support or disagree with previous studies	**Data analysis** is not well covered, **does not explains** how the results support or disagree with previous studies	**No/or inappropriate** discussions of the findings. **No comparison** with previous studies		X2	
Formulated conclusions	The conclusions are **justified** by the data provided. Formulates and **adequately supports meaningful** conclusions	Formulated conclusions are **acceptable**	Conclusions are **partially meaningful** and **incomplete**	Conclusions are **absent, wrong, trivial** or **unproven**		X1.5	
Recommendations for future work	Makes **insightful recommendations** and **succinctly addresses perspectives** for further research	Makes some **good recommendations** and perspectives for further research	Makes **broad or obvious** suggestions for future work	Makes **no plausible** suggestions for future work		X1	
References	The references are **appropriate** for the statements they are meant to support; they are **up-to-date.** They are properly **cited following** the guidelines	The references are **appropriate** but are **not up-to-date and/ or not cited following** the guidelines	References are **not supporting** the study; cited in an ad-hoc way (e.g. [1-10]), not **properly following** the guidelines	Most of the references are **not related** to the problem, **not up-to-date** and/or not **cited following** the guidelines		X1.5	
English composition, documents and structure	Consistently **well written; spelling, grammar, citations, references**, headings, page numbers and document sections	Manuscript **conforms to most standards** of English composition	Manuscript contains **several mistakes and bad use of tenses** and document sections **need improvement**	Manuscript contains **too many mistakes and bad use of tenses** and document sections are **not appropriate**		X1.5	
				Total			
				Supervisor total/20			
				Instructor total/10			

Grand total:

Comments and recommendation:

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