International Journal of Engineering Education Vol. 38, No. 2, pp. 482–490, 2022
Printed in Great Britain

0949-149X/91 $3.00+0.00

Literature Searching/Compiling/Understanding for Support of Student Research/Projects: A Dedicated Course Approach*

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Searching, compiling, understanding, and explaining the literature relative to one's research or project represents an essential 21st century skill for students. The innovation in the present work is that the *full range* of these diverse topics can be integrated and team taught, in a single unified course format. There is widespread awareness that the rapid advances in technology have greatly accelerated fundamental progress in science, engineering, and medicine as well as in the entrepreneurial development in these fields. Simultaneously, there have been, perhaps less publicized, advances in information science, database technology, literature searching tools, data compilation tools, and data sharing tools. To be competitive, students need to learn about and to incorporate these powerful tools into their research and engineering project work while they are in school and after graduation. Lessons learned in developing a productive academic research laboratory (Optics Laboratory at Georgia Tech) were used to formulate an inclusive suite of the needed topics and to introduce these via a course for undergraduate students to be team taught by an engineering professor and several librarians. After five offerings, this course has earned permanent listing. The resulting 2-credit hour elective ''Research Methods'' course has gotten high course evaluations. The course has enrolled not only the intended undergraduate students, but also has attracted graduate students, post-doctoral researchers, and faculty as well.

Keywords: Literature searching; database management; research methods; team teaching; educational software

1. Introduction

In a world where the pace of innovation is ever accelerating, students must exert themselves to keep up with the technological advances in their chosen fields. This is particularly true in their out-of-classroom research work and project activity. In all cases, these students are expected to be accountable for knowing and understanding the work published by others related to their own work. The level of understanding needs to be comprehensive and include current and future technology trends and directions. This is a daunting set of requirements. However, in parallel, with all the scientific and engineering technology advances, there have been significant advances in information science, database management, literature searching tools, and data compilation tools. To be competitive, students need to learn, as early as possible, about these powerful tools and incorporate them into their approach to their research and engineering projects. In present-day undergraduate engineering programs, it is now commonplace to have students involved in meaningful research projects in addition to their required design projects. Faculty involved in conducting/coordinating research and projects including senior design projects, in general, have a high expectation of the students. Similarly, the students have high expectations that they will be involved in research and projects of significance. However, in order to perform in an efficient and productive manner, students need to have the appropriate research skills including those for literature searching/compiling/understanding and communicating their findings. In many cases, past students have done their research/projects first and then attempted to do a literature search after the fact. This has frequently led to the embarrassment of finding prior work that has produced similar or perhaps even better results than the students were trying to achieve. This gives rise to disappointment on behalf of both the student and the faculty member. The innovation in the present work is that the broad range of topics needed can be unified, integrated and team taught in a single course.

2. Background

Non-credit workshops on research methods topics are typically offered through the university's library. These generally include instruction on literature searching [1], patents [2], reference management software [3–5], companies [6], impact measures [7], and more. However, being voluntary in nature and not carrying course credit, these piecemeal workshop opportunities are not as

* Accepted 6 November 2021.

widely used as they should be. Moreover, the need for efficient searching/compiling/understanding and then communicating the results has been well documented in the literature [8–26]. Numerous helpful articles have been written describing how to perform meaningful searches [27–44]. A variety of courses covering the above topics/methods and additional topics have been offered [45–58]. However, in general, there is still a need to have searching/compiling/understanding with communications unified and integrated together. In the present work, it is attempted to fulfill this need by introducing a dedicated undergraduate credit course. The content and approach for that course is described in this paper.

3. Overview

In a larger educational view, the present Research Methods course has been designed to facilitate critical thinking and digital competency in the students. The course guides students to enable them to locate, compile, manage, and understand the literature relative to their own research or project work and then to be able to communicate this understanding. Using current highly developed commercial databases and customized search strategies, students learn to find articles that are relevant to their research/project area. The overarching framework of the course integrates the same time management and project management principles that the students will need to apply in their research. Relative to their chosen topic, students are asked to answer these questions about their research/project: What is the impact? What have others done? What is missing? How does my research/project fit with what is missing? This strategy orients them to be able to communicate their results in an academic setting or a business setting.

4. Goals and Learning Outcomes

The course goals are to enable the student to locate, compile, manage, and understand the literature relative to their research or project and to communicate this understanding. The learning outcomes are that, upon completion of the course, each student has developed a database that includes at least (1) journal papers, (2) conference papers, (3) trade-journal articles, (4) theses, (5) patents, and (6) company information relevant to their research/project. This includes pdf copies of these items and written summaries with automated referencing that include prior references (backward search) and subsequent references (forward search) to the item being summarized. This produces a self-contained, completely searchable, and totally portable database. The student has also made an oral presentation of their results that includes impact, what others have done, what is missing, and how their work addresses the missing piece.

5. Course Description

This course is now a permanently listed two-credit-hour elective course at Georgia Tech: ECE 4053 Research Methods. In this course, techniques for the efficient searching of various databases (Table 1) available through the library are demonstrated.

This is accompanied by implementing a systematic procedure for compiling this information in a self-contained, transportable database based on the EndNote software [79]. The primary reference types covered are listed in Table 2. These include standard types of references such as journal papers and conference papers, but also equally important: theses, patents, and grants. In addition, the custom reference types of company, datasheet, instruction manual, roadmap, and software, which are not included in the commercial software, have been added using the built-in customizing features in the software. *This allows the researcher to have all of their literature and notes in a single portable database.*

Over 300 tutorial documents and videos are compiled on the course website. The topical headings are shown in Table 3. A complete listing of all

Table 1. List of commercial databases covered in Research Methods course

Applied Science and Technology Abstracts [59]	Optics Infobase [60]
Compendex [61]	ProQuest [62]
Derwent Innovation [63]	PubMed [64]
Dun & Bradstreet [65]	ResearchGate [66]
EBSCO Business [67]	S&P Global [68]
Google Scholar [69]	Scopus [70]
Grants.gov [71]	SPIE Digital Library [72]
IEEE Xplore [73]	USPTO [74]
Inspec [75]	Web of Science [76]
LexisNexis [77]	WorldCat [78]

Table 2. Primary reference types covered in Research Methods course

Book Section/Chapters	Instruction Manuals*	Software*
Companies*	Journal Papers	Theses
Conference Papers	Newspaper Articles	Trade-Journal Articles*
Datasheets*	Patents	Web-Page Articles
Grants	Roadmaps*	

* Denotes reference type added through customization option in EndNote software.

Table 3. Topical headings on Research methods course website [81]

1. Course Instructions	8. EndNote Tutorial Videos
2. EndNote Customization Files	9. Example EndNote Databse
3. Database Information	10. Report Writing
4. Database Tutorial Documents	11. Technical Oral Presentations
5. Database Tutorial Videos	12. IEEE Information
6. EndNote Information	13. Other Resources
7. EndNote Tutorial Documents	

322 items on the website is available in the supplementary materials [80].

The majority of the lectures are given by an ECE professor. In addition, individual librarians make presentations on searching, theses, patents, companies, grants, citation alerts, and EndNote. Starting with a given article, both forward (in time) and backward searching are demonstrated. Developing database advanced search strategies is covered. Setting automatic email alerts for citations to a reference or for papers matching a defined search strategy are described. In homework assignments, students are asked to perform and document these operations as applied to their chosen subject area. Throughout the course, the modern topics of evidence synthesis [82], meta-analysis [82], data visualization tools [83–85], mind-mapping tools [86, 87], concept-mapping tools [88, 89], and generating trend analysis graphs [76] are integrated into the course. A complete list of homework assignments is shown in Table 4. The assignments for the entire semester are posted before the first day of classes.

A description of the assignments is as follows: In the ''Class Survey Form,'' students supply information about their background and academic and entrepreneurial interests. In ''Download TurningPoint App,'' students download an app that allows them to answer pop-up questions that occur in each

Table 4. Homework assignments in Research Methods course (for spring semester 2021)

Assignment Number	Credit Homework Number	Assignment Title	Credit or Non-Credit	Due Date
1	–	Class Survey Form	Non-Credit	1 - 25
2	–	Download TurningPoint App	Non-Credit	1 - 25
3	–	Download EndNote	Non-Credit	1 - 25
4	1	Title and Abstract	Credit	1 - 27
5	2	Initial References	Credit	2 - 1
6	–	Customize EndNote	Non-Credit	2 - 1
7	–	Register for Citation Alerts	Non-Credit	2 - 1
8	3	Key Words Search	Credit	2 - 3
9	–	EndNote Groups	Non-Credit	2 - 10
10	4	Example Written Summary	Credit	2 - 15
11	5	First-Draft Database	Credit	3 - 1
12	6	Cited Reference Search	Credit	3 - 10
13	7	List of References to be Summarized	Credit	4 - 5
14	8	Second-Draft Database	Credit	4 - 7
15	9	Citation Alerts Received	Credit	4 - 14
16	10	Journal Terms List	Credit	4 - 19
17	11	Final Database	Credit	4 - 20
18	12	Oral Presentation	Credit	3 -31 4 - 20

Table 5. Distribution of grades in Research Methods course

Title and abstract (2%)	Second-draft database (10%)
Initial references (2%)	Citation alerts received (2%)
Key words search (2%)	Journals terms list (2%)
Example written summary (5%)	Final database (38%)
First-draft database (8%)	Oral presentation (15%)
Cited reference search (2%)	Participation (10%)
List of references with summaries (2%)	

lecture. In ''Download EndNote,'' students download the reference manager software to be used. In ''Title and Abstract,'' students submit their self-chosen research/project topic. In ''Initial References,'' students provide a list of their starting references. In ''Customize EndNote,'' students download files to enable additional reference types (companies, datasheets, instruction manuals, roadmaps, software, and trade-journal articles) and to provide standard abbreviations for journal names. In ''Register for Citation Alerts,'' students provide (1) a list of key papers on which they are receiving alerts that those papers have subsequently been cited and (2) the text sequence describing their topic search strategy. In ''EndNote Groups,'' students create the groupings within the software that they are using to classify the literature they are finding. This includes Smart Groups that automatically flag literature that contains user-specified keywords or phrases. In ''Example Written Summary,'' students submit a summary in the specified format of a relevant paper that they have found. In ''First-Draft Database,'' students submit a compressed file (*.enlx) of their database as it exists at about the 1/3 point in the semester. In ''Cited Reference Search,'' students submit a list of references obtained by forward searching from original key papers that they have identified. In ''List of Reference to be Summarized,'' students present a list of at least 12 papers on which they will submit detailed written summaries by the end of the semester. In ''Second-Draft Database,'' students submit a compressed file of their database as it exists at about the 2/3 point in the semester. In ''Citation Alerts Received,'' the students submit a list of references that have been located through their automated search strategy. In ''Journal Terms List,'' students submit a list of journal names that were not automatically abbreviated by the software. These abbreviations will be added to the master list. (The software supplier does not include abbreviations for engineering journals. Therefore, the needed list has been generated here.) In the ''Final Database'' assignment, students submit a compressed file of their final database. In ''Oral Presentations,'' students orally present with slides (1) their understanding of the background material for their project, (2) future directions for their work, and (3) searching techniques that they found to be helpful. These oral presentations are evaluated by the class as a whole. Students are graded for these individual assignments in the progression of intermediate steps (Table 4) that lead to their final database submissions and their oral presentations. The grade distribution for the course is shown in Table 5.

In the course, the databases that the students prepare have attached pdf copies of all their references as well as their own written summaries of the key papers that they have identified. From the student point-of-view, writing these summaries is perhaps the most demanding part of the course. This written material is to contain a summary of the article and, importantly, an explanation of how the reference relates to their own research/project topic. These written summaries are prepared in Microsoft Word [90] using the Cite While You Write (CWYW) [91] feature that is added into Word when the EndNote software is installed. This enables students to include citations to related work in their written summaries. These summaries are then included as file attachments to the article being summarized in their individual databases. As is standard in much of engineering, the IEEE format for references [92] is used throughout. These personalized databases then serve as the student's primary research organizational tool as they proceed going forward with their own projects or thesis work. Students are able to take these self-contained libraries (no internet connection needed) with them for continued use into whatever they do following graduation. They can do this by compressing their individual EndNote libraries or by transferring them to Zotero [93], a free and open source reference management software program with similar functionality to EndNote.

6. Assessment and Impact

From the official university course evaluation tool, Course Instructor Opinion Survey (CIOS) [94], the major items assessed by students in each class are ''Course: Amount Learned,'' ''Course: Structured for Feedback,'' ''Course: Feedback Helpfulness,''

Table 6. Five-year averages of major assessment items from the official university CIOS course evaluation tool

Assessment Item	Course 5-Year Average	Institute 5-Year Average
Amount Learned	4.54	4.10
Course Feedback	4.88	3.70
Course Assignments	4.60	4.05
Professor Effectiveness	4.70	4.10
Librarian Effectiveness	4.66	4.10

"Course: Assignments Facilitated Learning," "Assignments Measured Knowledge," and "Instructor: Overall Effectiveness." For the assessment presented here the two feedback survey responses were averaged together and the two assignment survey responses were averaged together. The survey results averaged over five years for the course and for all courses at Georgia Tech are presented in Table 6.

Overall, the Research Methods course was assessed to be more effective in all categories than the average for all courses at Georgia Tech. A year-by-year plot of the course assessment items are given in Fig. 1 starting in 2017 when the course was first introduced on a trial basis.

Written comments were requested year-by-year through the institute CIOS survey tool. *Detailed student and faculty written comments about the course are available in the supplementary materials* [81]. Of these, a noteworthy student unsolicited written comment was as follows:

> "Since this class is fairly new, I want to advocate it to any student involved in undergraduate research. It helped me develop an extensive understanding behind the background of my research field. Additionally, I feel that the work that I've compiled throughout the duration of this course will benefit my lab and future members that wish to read and learn about anything and everything related to this research."

A noteworthy faculty unsolicited written comment was as follows:

> "Research Methods course has been so helpful to all of the ORS (Opportunity Research Scholars) students. Alex (Herbets) has said it has really helped him with his project. He feels he is far ahead of the others based on what he has learned. They are all very enthusiastic about learning how to organize their research. I wanted to make sure that you were going to offer the course again. ORS would like to make an announcement at the appropriate time when the students can register."

A noteworthy administrator unsolicited written comment (Vice Provost) was as follows:

> "There are a number of very interesting components in this course.
> (1) Whole person education: This course fits in with the themes of the Commission on Creating the Next in Education report with regard to whole person education (critical thinking, communications, time/project management).
> (2) Foundational Skills: Research methods course like this give students the foundational skills needed to pursue their research projects much more effectively. For example, it gives them digital competency for understanding what has been done elsewhere in a more deliberate and less haphazard way. The critical thinking part is to identify gaps in knowledge (difficult, because you are seeking what isn't there). This means that you need to have a good picture of the knowledge that is there.
> (3) Digital competency: This course was developed and taught in collaboration with the library staff. It is an example of projects that can be done within the vision of the Library Next initiative."

A noteworthy sponsor unsolicited written comment (Research Program Manager) was as follows:

> "The creation of a new course under this research grant advances the building of next generation researchers, a critical broader impact of the National Science Foundation's research grants."

A year-by-year assessment of the instructor effectiveness as obtained through the institute CIOS survey tool is shown in Fig. 2.

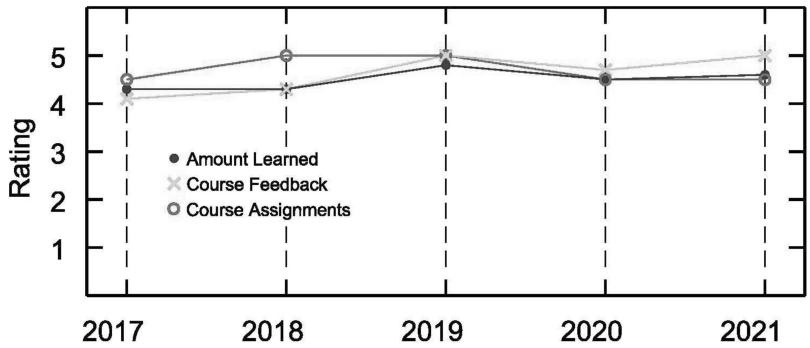

Fig. 1. Year-by-year student assessments of amount learned, course feedback, and course assignment from CIOS data.

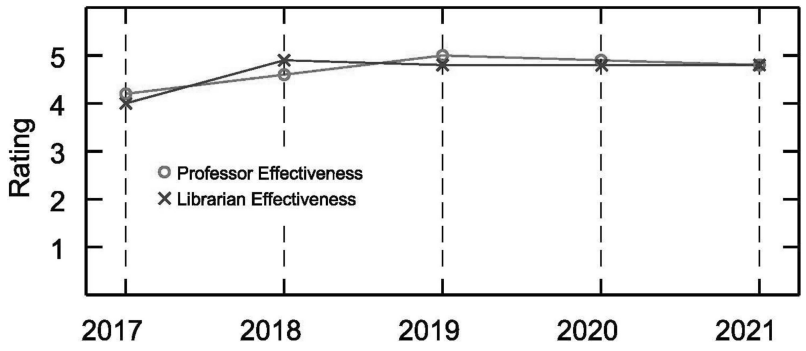

Fig. 2. Year-by-year student assessments of overall instructor effectiveness from CIOS data.

The apparent success of the course is perhaps not surprising, since the methods being presented are based on experience gained over an extended period of time in an academic research lab (the Optics Laboratory at Georgia Tech). As such, the approaches being taught in the course are not so much of a new educational experiment, as they are of a technology transfer from graduate research to the undergraduate curriculum. In addition to ECE students working on research with individual faculty members, the Research Methods course has attracted students engaged in the various campus-wide research programs at Georgia Tech including the Opportunity Research Scholars (ORS) program [95], the Vertically Integrated Projects (VIP) program [96], the Create-X program [97], the Undergraduate Research Opportunities Program (UROP) [98], the Grand Challenges program [99], the President's Undergraduate Research Program (PURA) [100], as well as Senior Design students.

The concepts and methods presented here are not unique to engineering. A corresponding course "Research Methodologies" has now been "spun off" in the Global Media and Culture Master's Degree Program at Georgia Tech [101]. This program awards a joint degree between the School of Modern Languages and the School of Literature, Media, and Communications. In fact, the research method approaches presented here are applicable across all fields of research. A further "spin off" has been the well-received half-day "Research Methods Workshop" offered for undergraduate students from other institutions who come to campus to participate in summer research programs such as Summer Undergraduate Research in Engineering/Science (SURE) [102] and Research Experiences for Undergraduates (REU) [103]. This workshop is given on the first day of these summer programs and it clearly seems to help "jump start" these short-duration student research projects.

7. Conclusions

Searching, compiling, understanding, and explaining the literature relative to one's project is fundamental to the process of research. It is a need that has traditionally been addressed in a piecemeal fashion. The above-described Research Methods course is an attempt to address this need in a unified and integrated way. The course has been offered five times and has now become a permanently listed two-credit hour elective course at Georgia Tech: ECE 4053 Research Methods. The resulting course has received high course evaluations. The course has not only enrolled the intended undergraduate students, but also has attracted graduate students, post-doctoral researchers, and faculty as well.

Acknowledgements – The authors gratefully acknowledge the support of this work in part through grant ECCS-1915971 from the Directorate for Engineering of the National Science Foundation. The authors also acknowledge the important contributions of librarians Marlee D. Givens, Lisha Li, and Patricia E. Kenly.

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