An Adaptive Research Support System for Students in Higher Education: Beyond Logging and Tracking

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Abstract. In this paper, we focus on design for an adaptive research support system that provides support for research activities of students in higher education, as well as improving the research skills of the students. Research activity is one of the core activities of institutions of higher education and it is with this in mind that we propose an adaptive research support system to improve the research skills of students. Research skills include such generic skills as planning and scheduling, communication and presentation; and specific skills such as trend analysis, problem definition and data analysis. We present a general way to improve research skills of students by adaptation, achieved through coaching and scaffolding supports using information gained from archived laboratory knowledge.

Keywords: Adaptation · Research support system · Research skills · Coaching · Scaffolding

1 Introduction

Research is one of the core activities of institutions of higher education. Therefore it follows that ways of improving research skills of the students is an important area of study. Teaching students research skills provides the students with information and facility for improving their research capacity, quality and productivity with the aim of better quality output, more effective and efficient research output from institutions of higher education.

Several studies have been conducted into ways to teach both general and discipline-related research skills to students. A Research Skills Framework (Willison and O'Regan 2007) is a conceptual framework that was developed to guide the teaching of undergraduate students in order to achieve explicit development of research skills. The framework can be used "to both chart and monitor students' research skill development" (Willison and O'Regan 2007) and to guide the student in progressing from the "commonly known, commonly not known to the totally unknown". In a paper by (Showman et al. 2013), they explain five essential research skills for undergraduates help them move from learning to discovering. These and other studies underpin the

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importance of equipping students with research skills right from the undergraduate level to the graduate level. However, one challenge is that research skills are cognitive skills which are difficult to teach and to evaluate because they are implicit.

Most institutions of higher education implement some sort of tracking or logging system to monitor and track students' research activities and to provide a tool for communication between students and their supervisors. These systems are usually used for quality assurance of the research process of the students. The monitoring and tracking systems, while helping students with logging their research activities and keep up with deadlines, have a few limitations. These include the fact that they are seldom adaptive with regards to the needs of each particular student, they do not preserve previous laboratory research knowledge, and do not offer a platform for students to improve their research skills.

A limitation of the existing tools and frameworks designed to improve the research skills of students is that they factors in the physical and continuous presence of a mentor or teacher, but in reality face-to-face interaction with the researchers may be minimal or may be a mixture of real and virtual laboratory. In addition, the students in higher education join a certain laboratory for a short time because of graduation timelines. This makes it difficult for them to learn the research skills properly.

An adaptive research support system can bridge this gap by offering a platform for students to learn invaluable research skills while they carry out their research activities. In adaptation, for example, students who are carrying out a task for the first time will be provided with relevant information and step by step support to accomplish the task, while advanced students will be given more challenging tasks to encourage them to find creative ways to solve problems on their own.

The target of our proposed adaptive research support system is students in all levels of higher education: undergraduate, master's and doctoral students or their equivalents. Research students in general could benefit from making use of the system. The research should ideally be organized in laboratory format, where students carrying out research in a common area or theme are grouped together under one professor such as in STEM where faculty and students often collaborate on common problems of inquiry (Franke and Arvidsson 2011). Research organized under a common theme will enable preservation of relevant laboratory knowledge which will be exploited for the implementation of adaptation.

The goal of the adaptive research support system is to support academic research activities while improving the research skills of the research students. Research skills include such generic skills as planning and scheduling, communication and presentation; and specific skills such as trend analysis, problem definition and data analysis. Improving research skills of students through our adaptive systems is a key and unique goal that highlights the originality of this research. The motivation of our research is that students in higher education need adequate interaction with professors in order to improve their research skills but this is not always possible especially in developing countries where the ratio of students to professors may be higher, and in the case of distance learning where contact with the professors may be minimal.

The following sections are constructed as follows: in the second section, we describe in detail the research activity process, the specific definition of research skills, and we

present a review of related literature. In Sect. 3, we discuss our general design approach for an adaptive system to improve research skills. Section 4 includes the conclusion and future works.

2 The Research Activity Process and Review of Related Work

2.1 The Research Activity Cycle

Most of scientific research follows a common cycle that can be abstracted as shown in Fig. 1. We base this representation on The Research Process Model by (Fankfort-Nachmias and Nachmias 1992) showing the main steps in scientific research. This research activity process is more or less the same for all disciplines (Lynch 2013). Lynch further notes that "the key difference across disciplines is in the subject matter, and therefore, the type of data used and the methods for gathering it".

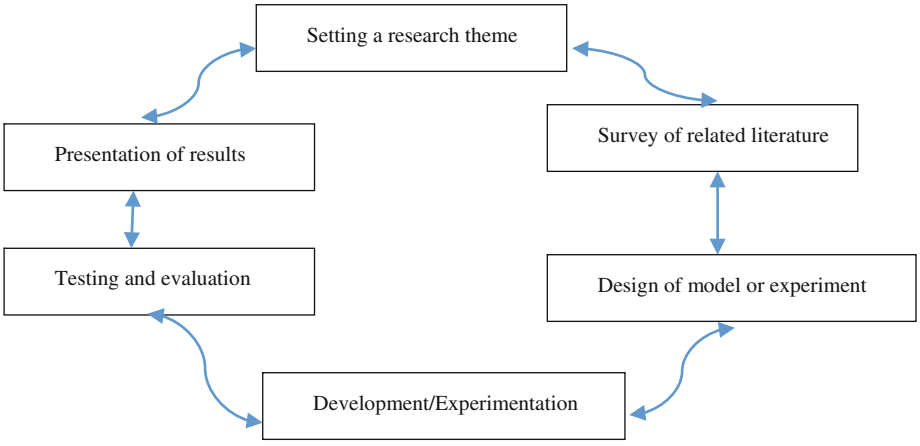

Fig. 1. Research activity cycle

In **setting a research theme**, the aim is to identify a topic of interest to study. **Survey of related literature** involves exploring the works of fellow researchers. After surveying related works, a researcher may go back to the first step to modify their problem statement. The research cycle is not unidirectional and is also not strictly sequential. The **design of model or experiment phase** involves creating a plan, considering expected findings, tools, methodologies and designing experiments or models**. Development or experimentation** phase involves carrying out the experiment or developing the software or tool in the case of information science. **Testing and evaluation** involves collecting data and analyzing it using statistical packages, for example. Presentation of results involves publishing in books/journals, web publication, presenting at seminars and conferences and so on.

2.2 Research Skills

Research skills are necessary for students to improve their research capacity, quality and productivity with the aim of better quality output, more effective and efficient research output from institutions. However, research skills are cognitive skills that are hard to teach, to learn and to evaluate. What exactly are research skills? Research skills can be widely categorized into two: discipline specific and general research skills. While there may be several types of research skills, the key idea of our research is to develop and improve research skills from a low degree of autonomy corresponding to closed inquiry and high degree of guidance, to a high degree of autonomy where students conduct open inquiry within self-determined guidelines (Willison and O'Regan 2007).

Depending on what stage of the research activity cycle students are in, Table 1 shows examples of the crucial skills students in higher education carrying out research should develop.

Table 1. Research activities and corresponding skills

Research activity	Specific skills	Generic skills
Setting a research theme	• Trend analysis • Problem definition	• Planning/scheduling • Communication • Self-directed and motivated • Creativity/innovation
Survey of related literature	• Information retrieval • Reading • Evaluation	
Design of model or experiment	• Design • Discipline-specific skills	
Development/experimentation	• Discipline-specific skills	
Testing and evaluation	• Analytical • Evaluation	
Presentation of results	• Presentation	

2.3 Related Works

There has been previous research into tools and systems to support students with their research activities. In their research, (Hasegawa et al. 2007) created a portal site to manage all content created during the research activity cycle through seamlessly integrating activities support services. Their research demonstrated success in two web services: setting a research theme and trend analysis (review of related literature), saving students efforts at this stage of the research activity cycle.

Other researchers have reported positive findings in recommending relevant research resources to assist researchers with the literature review process. (Porcel et al. 2008) concluded that their system was effective in enabling researchers to obtain automatically information about research resources interesting for them; (Bandara et al. 2011) proposed an extensive tool support for the identification of appropriate papers during the literature review process. (Kiah et al. 2014) developed a customizable search engine for trusted resources in medical informatics.

Previous research has mainly been focused on improving specific areas of the activity research cycle such as setting a research theme and survey of related literature. Some previous research has focused on the entire research activity cycle such as the proposed framework for a web-based research support system by (Yao 2003) where various research activities are linked to different systems that support those activities. The paper combined computer technology and research methods to develop a conceptual framework for research support systems. Yao not only links activities to support tools, but also notes that an adequate research support system would need to be adaptive to the scientist and states the need for applying algorithms to documents stored to "discover patterns and extract knowledge useful to a user".

A practical example of a system that extracts previous knowledge from stored documents is the article revising system by (Hasegawa and Yamane 2011) where the system extracted laboratory knowledge from the information accumulated from laboratory members. There has also been research into improvement of presentation and communication skills. In their study, (Kerby and Romine 2009) state that students can improve their oral presentation skills by, among other ways, experiencing consistent instructor feedback.

Previous research has focused on improving some of the research skills of its students in order to increase efficiency and reducing the efforts required to carry out some of the research activities. However, there has been no specific research support system (computer system) whose explicit goal is to improve research skills of students and our aim in this paper is to present the design for such a system.

3 Design Approach: Adaptation for Improvement of Research Skills

Research skills are cognitive skills that are therefore difficult to teach and evaluate. The Cognitive Apprenticeship Theory was originally proposed by Collins et al. (1989). It proposed a way to apply features of traditional apprenticeship in teaching cognitive skills by following the 6 steps in order: modeling, coaching, scaffolding, articulation, reflection, and exploration.

Our approach is to combine content (research knowledge) with metacognitive support (modeling, coaching, and scaffolding) to improve the students' research skills. Adaptation relies mainly on coaching and scaffolding; to improve research skills we need to reduce the cognitive support for the students as their level of skill increases. This approach is called fading scaffolding/fading, where functions of the supporting tool can be *fadable* according to the student's meta-cognitive skill (Kashihara et al. 2008).

In designing a research support system to improve the skills of students, we need to deal with the following issues:

- how to represent the research activity process
- how to estimate the student level
- how to provide coaching and scaffolding

3.1 How to Represent the Research Activity Process

Each phase in the research process (refer to Fig. 1) will be represented as a research outcome in the system. At each phase of the research activity cycle, students produce research artifacts such as documents, presentations, and data in various forms, among others. These research artifacts will usually undergo revision with the supervisor giving comments to students in order to help improve the work product. We propose to have students upload their work product into the system and the supervisor to use the same system to give comments which the students will use to improve their work product. In this regard, it would work like an issue or incident tracking system (refer to Fig. 2). The system will keep track of the revision history of the artifacts as well as the comments associated with the revised documents. All the document versions and associated comments will be stored and analyzed in order to improve the knowledge base that will be used to provide coaching and scaffolding for future students.

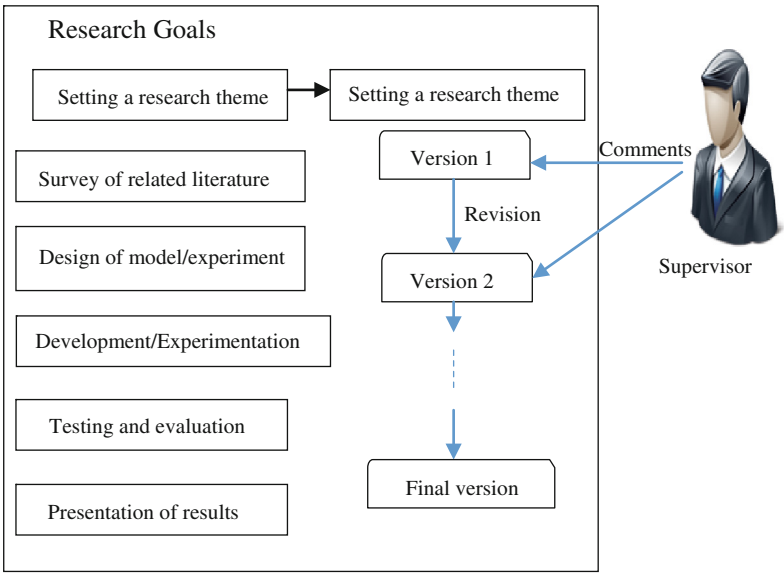

Fig. 2. Overview of the research support system interface

3.2 How to Estimate the Student Level

In order for the system to be adaptive to the research skill needs of students, it must be able to estimate their initial and continued skill levels. Initial estimation of student skill may depend on previous work carried by the students and uploaded for evaluation into the system. Additionally, undergraduate students may initially be estimated to be at beginner level, master's students at an intermediate level, and doctoral students at an

advanced level. These levels are not fixed and for example, an undergraduate students can muster a skill and move to an advanced level. The system will be adaptive and will keep a student in a relevant category as their skill level changes.

To monitor and track student progress in achieving a certain skill, the evaluation function will take into account two factors: process and outcome. For process evaluation, we will consider factors such as the number of comments, the type of comments, the draft history and the duration of revision. Outcome evaluation is much harder to carry out as it depends on factors such as the quality, originality and effectiveness of the student's work product.

We will divide student skills into five levels according to the Research Skills Framework (Willison and O'Regan 2007). These will form a basis for providing coaching and adaptation as will be discussed in Sect. 3.3.

3.3 How to Provide Coaching and Scaffolding

Providing coaching and scaffolding, in addition to the evaluation function discussed in Sect. 3.2, will form the core functions of the adaptive system in order to improve the research skills of students. The input to our system will be students' research artifacts, comments from the supervisor and responses to the comments by the students, and any learning resources the supervisor might provide. The processing will include managing student information, managing and tracking research artifacts and revision history, evaluating the student level, analyzing content to generate rules to associate research skill level with appropriate resources, coaching and scaffolding. Output from the system will be feedback and guidance to students, and statistical trends.

We will provide coaching and scaffolding during the artifact revision process. Coaching will involve letting the student to do carry out a task but providing guidance as to how the task can be achieved. With scaffolding, the guidance provided to the student will reduce with time as the student's skill level grows. Once the student receives feedback in form of comments from the supervisor, the next step for the student is to revise the current draft. The system will analyze the current comment by comparing it to similar existing comments in the knowledge database and provide appropriate support and guidance (coaching) depending on the student level (see an example in Table 2). Even for similar comments, the system will provide different guidance to students in different skill levels. If a student gets a similar comment in the future but their skill level is different, they will get different guidance. As the student's skill level increases, this guidance becomes less and less (scaffolding). If the student's level stays the same or decreases over a certain period of time, this can be flagged by the system and the supervisor can take appropriate action.

In Table 2, we show an example for improving the modeling skills of students carrying out research in information systems. After setting a research theme (formulating the problem) and reviewing related literature, the students have to come up with a graphical representation of their proposed system (modeling phase).

Table 2. Providing coaching and scaffolding in learning modeling skills

Skill level	Design of model
Level 1	• System gives several examples of similar comments and revised artifacts • System/supervisor specifies which modeling methodology to use
Level 2	• System gives some examples of similar comments and revised artifacts • System provides 2–3 ways of modeling for the student to choose from
Level 3	• System provides examples only on request • System provides from all possible modeling ways for students to choose from
Level 4	• System does not provide examples • System provides from all possible modeling ways for student to choose most suitable
Level 5	• System challenges student to come up with their own original way of modeling if existing ways are not sufficient in some way

4 Conclusion and Future Work

In this paper, we proposed a way to improve the research skills of students using an adaptive research support system. This involves using the cognitive apprenticeship theory in teaching research skills since they are cognitive skills that are hard to teach and to evaluate. By using computer technology to provide coaching and scaffolding to students during the revision of research artifacts produced during the research process cycle, we posit that it is possible to improve the research skills of students. This will result in better conception, development and representation of research ideas from unstructured to highly structured and independent which will lead to shortening time the time it takes to conduct research while at the same time increasing efficiency and quality.

In future work, we will develop and implement the system based on the design discussed in Sect. 3, and design experiments to test out the effectiveness of the system. We will focus on the design model/experiment phase of research, and we aim to test this system with students carrying out research in information systems research field. Students will at this stage develop a graphical representation of their proposed information system using modeling languages such as Unified Modeling Language, and we will test whether their modeling skills will improve with time. We will collect all system data including logs of students' interaction with the system, and conduct pre-and-post interviews. We will analyze this data to identify meaningful patterns and emerging themes for further research.

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