Katrina Falkner and Nickolas J.G. Falkner

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Integrating Communication Skills into the Computer Science Curriculum

Katrina Falkner
School of Computer Science
The University of Adelaide
Adelaide, South Australia, Australia, 5005
katrina.falkner@adelaide.edu.au

Nickolas J.G. Falkner
School of Computer Science
The University of Adelaide
Adelaide, South Australia, Australia, 5005
nickolas.falkner@adelaide.edu.au

ABSTRACT

Computer Science majors must be able to communicate effectively. Industry surveys identify the development of communication and critical thinking skills as key to the reform of the higher education sector. However, academics are challenged by time and discipline content pressures, as well as a lack of familiarity with the teaching and assessment of communication skills content. There is considerable existing work in the area of communication skills development, positioned both in terms of curriculum guidelines for effective communication skills development, and example communication skills activities. However, this research is deficient in detailed, contextualised methodologies and frameworks for the development of communication skills within the Computer Science curriculum. We present a new methodology, building upon well established theoretical frameworks, designed to assist academics in the development of communication skills activities integrated with discipline content across the curriculum. We illustrate this methodology in the design of a CS1/CS2 communication skills course.

Categories and Subject Descriptors

K.3 [**Computers & Education**]: Computers and Information Science Education

General Terms

Human Factors

Keywords

Communication Skills, Curriculum Design, CS1/CS2

1. INTRODUCTION

Academics and industry bodies both recognise that Computer Science students are characteristically grouped at the middle and lower end of the spectrum of communication skills. The 2009 Australian Learning and Teaching Council (ALTC) report, *Managing Educational Change in the ICT discipline at the Tertiary Education Level*, identifies the teaching of personal skills, including communication of all kinds, as a key area for curriculum reform in the sector [15]. Employers identified communication and problem-solving skills as the areas most in need for improvement.

Communication skills are crucial to the careers of Computer Science graduates. Graduates tend to be more successful when they demonstrate good communication skills and the ability to communicate clearly within a broad range of settings [8]. The increasingly inter-disciplinary and international nature of the Computer Science industry requires professionals to be able to communicate clearly with clients and colleagues, beyond the simple need to produce clear and understandable software and software documentation. Pomykalski [23] states 'the inability to write and think critically put information systems professionals at risk of being left behind in a rapidly changing technological environment'.

The development of communication skills is more than the development of effective writing and presentation skills for communicating with peers. A professional must learn to communicate within the language of their discipline, and to also communicate in the language used by readers or listeners outside of the discipline. Communication, both spoken and written, is a crucial tool in the development of critical thinking skills and in support of the development of discipline knowledge. Emig [6] discusses the broader underpinnings of the relationship between writing and learning, drawing our attention to the established belief that higher cognitive functions develop most fully when supported by communications activities.

Why do Computer Science students rarely receive the degree of training in communication skills development that is called for by both academic and industry groups? Very few Computer Science curricula include a core course that incorporates the development of communication skills in the context of computer science and, where these courses do exist, the focus of these courses is on general writing skills, rather than oral skills or professional communication skills [18, 10]. An increasingly crowded curriculum leaves little room for the development of non-technical areas [19].

We introduce a new methodology for the development of communication skills within the Computer Science curriculum, building upon well established theoretical frameworks for understanding and designing communication skills activities. We extend these approaches through a methodology for (a) identification of communication skills activities that provide depth and breadth in skill development, and (b) their composition and integration with discipline content and as-

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sessment activities. To demonstrate our new methodology, we provide several examples of extended and new activities and demonstrate their inclusion in an integrated curriculum.

2. RELATED WORK

The ability for students to reflect upon the need for communication skills in their future careers is key to their learning. Placing the teaching of communication skills within a discipline context is more engaging and crucial in the long term recollection and application of these skills [1]. Several studies have reported on Communication Skills courses designed for the Computer Science context, both as independent courses [14, 12] and through integrating communication skills content within an existing course [4, 16, 21, 22]. Independent courses, the majority, are often tangentially placed within the discipline context, and fail to include discipline-specific tasks. Students are, therefore, unable to relate the writing activities directly to their experiences of the discipline [12], missing an opportunity to express information about their discipline in new and productive ways.

Kay [14] introduces a dedicated communication skills course for Computer Scientists that contains a wide range of communications activities including technical writing, oral presentations and writing for electronic media. Kay proposes the inclusion of a specialised technical context through the construction of a simple prototype software system around which example assignments can be framed. Michael [21] builds upon Kay's work to identify the strategies required in constructing an integrated communication skills course for Computer Scientists. Fell *et al* [7] identify a set of writing assignments that may be used from introductory to advanced courses. Several authors have defined course structures for specific discipline courses, including data structures [13] and junior programming [21]. Pollock [22] discusses the structure of a graduate level course with an emphasis on writing for developing research skills, while Derrick [3] presents strategies for efficient assessment within a similar context.

In this paper, we move beyond the definition of a single communications skill activity or course, to present a methodology for the construction of communication skills curricula for the Computer Science discipline. Fell *et al* [7] present a summary of writing in CS courses, and examples of integrating communication skills components within common discipline assignments in introductory and advanced programming courses. Kussmaul [17] develops a methodology for developing communication skills based on Agile methods.

Dugan and Polanski [5] present a taxonomy of writing tasks, defined by writing for learning, writing for academic communication, and writing for industrial communication, and a general guide to incorporating writing into any computer science course. This taxonomy can be used to select a specific subset of writing tasks appropriate for the purpose and experience of the students. Taffe [25] identifies three categories of writing within Computer Science: writing to develop facility with the language of the discipline; writing to explain results of a study; and writing as a process of clarification. Despite their contribution, these studies neglect the perspective of developing communication skills in both depth and breadth across the curriculum.

Perhaps the most successful approaches to teaching communication skills are those based on Fulwiler and Young's Writing Across the Curriculum (WAC) [9]. WAC describes an approach whereby writing is integrated across all courses within the curriculum, and used as an active learning approach to facilitate the development of both non-technical and technical skills. The WAC model is based on the following principles:

- writing is the responsibility of the entire academic community,
- writing must be integrated across departmental boundaries,
- writing instruction must be continuous during all four years of undergraduate education,
- writing promotes learning, and
- students begin to communicate effectively within an academic discipline only by practising the conventions of that discipline.

The consistent integration throughout a curriculum, based on WAC, identifies communication as a *requirement* of the discipline. Further, it allows students to experience the learning impact of communication and assists them in adopting communication as a learning tool. Teaching communication in context encourages students to use the direct explication of writing skills to develop an awareness of, and habitual use of, communication, both in general and in discipline specific communication.

Consistent integration of communication skills promotes opportunities for practice and reflective development; it is well recognised that practise is a crucial component in the process towards achieving expertise in an area [24] and this is no different in the development of communication skills. Further, the development of expertise in communication promotes the development of discipline expertise: students' understanding of the discipline content associated with communication tasks correlates to the degree of practise, and number of tasks undertaken [2].

3. PROPOSED METHODOLOGY

We build upon, and extend, the well established framework of WAC and the categorisation work of Taffe to define a methodology for understanding and designing communication skills curricula. This new methodology enables academics to identify activities that demonstrate depth and breadth in communication skills development. A matrix assists academics in the selection and appropriate composition of activities, with an accompanying series of principles that assist academics in integration with discipline content.

3.1 Theoretical Foundations

Developing facility with the language of Computer Science requires two areas of focus: learning to understand and apply the technical concepts introduced, and learning to communicate these concepts in both specialised and ordinary language in ways appropriate to the audience. Writing to explain the results of a study incorporates the more formal communications tasks undertaken by discipline professionals, including user documentation, performance reports and software documentation, as well as more informal communications, such as presentations, program summaries and discussions. It is this category that is commonly integrated into the Computer Science curriculum.

Table 1: A Matrix for Communication Skills Activity Identification.

depth

	Developing Facility	Explanation and Description	Clarification
WTL	Reflections (journals, blogs), Question posing	One Minute Activities (designs, program summaries), forum postings, email	Reflections (journals, blogs); One Minute Activities (concept summaries, essays); Question posing
WID	Concept Maps; Glossaries; Resume; Thesis Statement; Experimental Descriptions; Citation	Portfolios; Project Reports; User Documentation; Essays; APIs; Online Documentation; Demonstrations	Project Proposals; Thesis Statement; Article Reviews; Program Comparisons; Program Summaries; Meeting minutes; Group discussion and debates
CDC	Innovation Report; Performance Report; Lab Reports; Presentations		

WAC programs typically promote the use of Writing to Learn (WTL) activities: informal writing assignments that enable *students* to analyse and develop key concepts presented in a course. This is in contrast to Writing in the Discipline (WID) activities, which model the formal communication required for *professionals* within a discipline. Incorporating both WTL and WID tasks within a curriculum is necessary as the capacity built through the completion of WTL activities leads to the ability to successfully attempt WID activities [20].

3.2 Developing Curricula

Our methodology combines the categorisations introduced by WAC and Taffe to develop a matrix of communication skills categories that guide the inclusion of communication skills activities within the Computer Science curriculum (Table 1). The matrix acts as a curriculum mapping tool that can be used to ascertain expected depth and breadth in exposure to communication skills development within a curriculum. In addition to the categories of WTL and WID, we define a new category, Communicating Discipline Content (CDC), which represents the deepest level of communication within the discipline while, concurrently, enabling students to model the full range of Computer Science communication skills.

Table 1 illustrates both the classification of communication skills activities when combining both categorisations and how these activities may be combined to achieve both depth and breadth. When both categorisations are viewed together, with the appropriate classification of activities, we are able to identify more precisely the aspect of skill development that is being addressed. For example, using this matrix, we are able to identify that although the selection of *reflections* and *user documentation* provide depth through the development from WTL to WID, they are each addressing a different form of Computer Science communication, and hence the desired bridging between activities is not achieved. Similarly, the combination of an *experimental description*, *performance report*, and *program summary* can be combined to demonstrate the spectrum of discipline communication skills. This particular combination of WID activities, however, we can identify as more appropriate for an advanced course where students have had prior opportunity to develop their expertise through informal WTL activities.

Our matrix enables faculty to determine a target aspect of skill development: how we can design courses to provide the intended depth, breadth, or combination, that is intended. For example, the selection of *reflections* as an activity can be combined with a *concept map* in order to provide deep *development of facility* with the discipline language. Similar activities are represented at different points within the matrix, for example the classification of *one-minutes activities*. This demonstrates the utility of a single activity in developing multiple skill areas - and the importance of recognising these activities as such so that they can be framed and assessed appropriately.

We identify four communication skills activities within the CDC category: *innovation report*, *performance report*, *laboratory report* and *presentation*. These activities represent the culmination of skill development in terms of depth gained through experience in WTL and WID activities, and span Taffe's categories.

3.3 Guiding Principles

We identify four principles to guide both the selection of activities from the provided matrix, and their integration with discipline courses.

1. Link communication skills activities with discipline activities and course objectives to provide motivation, engagement and active learning.

2. Bridge informal to formal activities, to enable modeling of communication via informal activities and application within the discipline to provide a professional perspective.

3. Use a range of activities that reflect the different types of writing undertaken by Computer Science professionals, including the kind of communication involved (as per Taffe), and communicating for a range of audiences, a range of mediums and levels of interactivity.

4. Use self- and peer-assessment where appropriate to engage students further in the reflection and review process, and provide opportunities for informal grading and feedback.

The principles we define assist faculty to identify communication skills activities that work with their existing discipline content or assessment tasks. Gribbin advises that one 'need look no further than the course objectives stated in the syllabus' when designing communication skills activities [11]. This statement makes a direct connection between each writing or speaking activity and the discipline objective that it is supporting. Communication skills activities are complementary to discipline content; they are designed to aid understanding of the discipline content, engaging the

Table 2: An Example Curriculum.

depth

	Developing Facility	Explanation and Description	Clarification
WTL	Reflections (blogs)	One Minute Activities (designs, program summaries)	Reflections (blogs); One Minute Activities (concept summaries)
WID	Glossaries; Citation	APIs; Online Documentation;	Group discussion and debates
CDC	Innovation Report; Performance Report; Presentations		

students through their independent study and assignment work to explore further the discipline concepts.

Many discipline academics are also reluctant to adopt significant communication skills assignments in their courses because of the perceived time required for assessment and evaluation of these assignments [11]. However, not all communications assignments require formal grading. Peer review is a commonly used form of assessment for informal learning activities, providing the valuable components of assessment and feedback, while further encouraging analysis and reflection within the class.

3.4 Implementation

To demonstrate our methodology, we define the activities and structure of a pilot communication skills course designed to be taught in an integrated fashion across two discipline courses - an introductory programming course and a data structures course[1]. We apply our methodology in both the selection of activities (as illustrated in Table 2), and in their integration with discipline content.

We can immediately identify the need to include several WTL activities, as these activities will serve as the bedrock for future communication skill development, and will enable students to develop good learning behaviours built around communication. However, it is also necessary to include aligned WID activities to encourage skill development within the discipline, developing communication skills and enabling deeper learning of discipline concepts. The course structure culminates with the inclusion of CDC activities, to provide a unifying activity within the discipline combining all forms of Computer Science communication. Detailed assessment criteria, in the form of rubrics, are provided for each activity, with an emphasis on understanding assessment criteria integrated into the assessment of all activities.

3.4.1 Developing Facility

Personal *reflections* in a journal or blog enable students to write freely about their study experiences, their transition to tertiary study and the associated assessment practices. In the context of developing facility, reflections encourage students to learn and use the language of their discipline and study environment.

The *glossary* activities require weekly contributions to an online collaborative glossary, with each student required to contribute one new entry, or add discussion to an existing entry each week with appropriate citation for all sources, contributing an element of peer review and feedback. This activity provides practice in the use of language within the discipline, through the development of a discipline tool that can be used throughout the remainder of their studies.

3.4.2 Explanation and Description

Informal *One Minute Activities* require students to complete a small communications task prior to, or during, class that is related to a concept or assessment task from their discipline courses. In the context of explanation and description, we focus on the use of small design tasks or program summaries, primarily targetting the understanding of fundamental programming concepts and the application of those concepts through the development and analysis of brief code segments [26]. Again, peer review and feedback can be incorporated to provide regular, informal feedback and opportunities for reflection.

- Write a pseudo-code description of the following algorithm: ...
- Explain the design of the algorithm that you have developed for this assignment...

Building upon the One Minute Activities, we define a combined *API* and *online documentation* WID activity, involving the development of detailed online Application Programming Interface (API) documentation for a Java class that students had developed in their introductory programming course. Students were required to use the Javadoc environment to develop their API documentation, and were asked to provide a psuedo-formal algorithm description for each method in their class, identifying any special cases and providing an explanation of data used in the method. Students were also asked to provide several examples of the usage of each method, highlighting special cases. This activity enabled students to develop a better understanding of object oriented design and the algorithms they had designed and implemented.

3.4.3 Clarification

Reflections and One Minute Activities are also used for their ability to aid clarification. In their regular reflections, students are able to move beyond use of the discipline language to clarification of concepts, aiding by self review of their reflections each week to observe their own development. In this context, concept summaries are adopted as the One Minute Activity, again influenced by Zobel [26]. For this subset of One Minute Activities, we integrated a group discussion element to mimic professional behaviour, bridging directly from WTL to WID.

[1]In our case study, the communication skills course exists as a separate course as it is undertaken by a specialised cohort of international students, from multiple prior institutions, however, these activities could be as easily embedded directly into the discipline courses.

- Select a section of your textbook (less than 1 page) and identify the five main points.
- Take the five main points you constructed earlier and rewrite the section without looking at it.
- Select a section from your textbook (1-2 pages) and summarise it in 500 words. Repeat this using 400 words, then 300 words and finally 100 words. Which is the best version?

3.4.4 Communicating Discipline Content

Our new CDC category highlights discipline activities that build further upon the skills developed in WTL and WID, combining skills chosen from the range of developing facility through to clarification. In our course structure, we adopt three activities to illustrate CSC: the *innovation report*, *performance report* and *presentations*. These activities effectively act as *capstone* experiences in relation to the development of communication skills, enabling students to further develop and also evaluate their skill development.

Perhaps the most engaging of the communication skills activities, the Innovation Report requires students to research and write a report on an innovative technology of their choice. Demonstrating the creativity and breadth within Computer Science, this assignment asked students to identify a new innovation, provide evidence of the innovative nature and give a brief description of how this innovation might change our world. The Innovation Report enables students to develop their research skills within their discipline, and requires them to master discipline concepts in order to understand their innovation. The Innovation Report provides the opportunity for students to demonstrate each category of language skill: facility, explanation and description and clarification, and through its extension in the presentation skills activity (below) utilises multiple communication mediums. Sample topics were provided to the students, including: the influence of cloud computing on high performance computing, nanocomputing, touch screen devices, and the integration of technology into every day items.

Presentation activities are included throughout the course structure, typically building upon the One Minute Activities embedded throughout. These presentations enabled students to further embed the skills associated with those homework activities through the use of several communication mediums, whilst also acknowledging the student preference for a specific communication medium. In addition, we included two more substantial presentations, the first on a discipline topic of the students' choice, enabling students to build familiarity in the use of formal presentation tools and structure, and the second a presentation on their Innovation Report. This second presentation employed the same presentation tools, structure, and assessment criteria. In this presentation, students were also asked to complete peer-assessment for one other student. Building from the feedback from their WTL presentation enabled students to reflect upon their own assessment and assessment criteria.

The performance analysis report requires students to analyse, compare and report on the complexity analysis of two data structures studied in their discipline course. This activity again provides elements from developing facility to clarification, in that it consists of several sub-activities: starting with the identification of their hypothesis - *verification of algorithmic complexity*, the design of a series of experiments to test their hypothesis, the design and completion of a test code suite to undertake their experiments and the final write-up of all of the stages along with the analysis of their results. This activity was designed to develop understanding of complexity analysis (typically a challenging topic for our students), the process of performance analysis, as well as models for documenting performance information.

3.5 Findings

In our analysis we explore the impact of continual exposure of communication skills development in a pilot study, following the first cohort who have taken this course and subsequently graduated. Students found the activities in the communication skills course to be more challenging than those they had previously undertaken in general communications skills courses. This is unsurprising, in that our expectations were greater: students are developing discipline knowledge concurrently with facility with communication. However, students also found these activities more rewarding and helpful in developing their understanding of discipline content. Perhaps the best way to analyse the impact of the communication skills activities is to ascertain whether the students involved in the course felt the impact of the course activities on their communication skills and their understanding of discipline content. It is worth noting here that these students are international students undertaking their first semester of study, and as such are unfamiliar with both informal and formal communication in English. Within the Reflections exercise, students wrote freely about their experiences, and reflected upon both the changes to their learning and understanding of appropriate study skills:

> *This week I started to prepare my performance analysis report. It was my first time to do write this kind of report. It is much harder. I needed to test more and analysis the programs much deeper. It was a good way for me to understand the programs what I need to analysis.*

> *All the week, every classmate are working on the practical exercises. It is really a hard work for a newcomer student. Frequently, I think I have mastered the knowledge after took the lecture, however, once I'm in practice in front of the computer, I found it's not quite as I thought before. Even more, I can not run a program. I believe that is the main difference between practice and merely thinking.*

We have been able to observe the performance and behaviour of this pilot group across their program of study. Course Coordinators for the related discipline courses have reported increased facility by these students in understanding assessment tasks and completing language-rich assessments. Final examination questions for these courses were classified as either mathematical or linguistic, based on whether the question could be solved using a mathematical solving method, or required deeper understanding and discussion of concepts. Students who had undertaken the communications skills activities achieved better performance in the linguistic questions than previous cohorts, as they were able extract more information from the question and then provide an answer in a way that matched more appropriately the assessment

criteria of the question. There were fewer examples of repetition from the course notes than had been seen previously. The results achieved by this initial cohort have indicated that exposure to integrated communication skills activities is of benefit. In their commencing year, these students represented approximately 25% of overall enrolments in undergraduate Computer Science programs (N=134). In general, the load pass rate for domestic Computer Science students within our institution is 83%, and for international students, 79%. The students from our cohort, also international students, demonstrated a load pass rate of 89% over the duration of their studies. However, there is considerable research to be undertaken before any true correlation can be identified. It is not surprising that students who are exposed to greater opportunities for communication skill development are able to perform to a higher standard in communication skills tasks. We intend to pursue a larger scale study using our methodology, applied to a broader range of students, exploring the usefulness of our methodology for Computer Science academics and impact upon student success.

4. CONCLUSIONS

Communication skills has been identified as a crucial skill area for Computer Scientists, both in the professional day to day activities and in the development of critical thinking and analysis skills. This paper presents a methodology for the development of communication skills curricula within Computer Science that encourages the use of communication skills activities throughout discipline curricula to facilitate both the development of discipline and professional skills. We present several examples of communication skills activities developed using our methodology, in the context of a communication skills course aligned with introductory Computer Science content.

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