

A preliminary categorization of what mathematics undergraduate students include on exam “crib sheets”

Antony Edwards
Swinburne University of Technology

Birgit Loch
Swinburne University of Technology

Many undergraduate examinations permit students to use a limited quantity of previously prepared notes: so-called “crib sheets”, or “cheat-sheets”. The majority of evidence from the literature suggests that students sitting such exams feel less anxious, and that they perform to a higher standard, although such results are idiosyncratic to discipline and course, and few are set in the context of undergraduate mathematics. Less is known about what content students choose to include on such a sheet, and how they interact with this material. This preliminary research report presents the first results from a three-year project investigating students’ use of crib sheets in undergraduate mathematics exams. It explores the content and layout of crib sheets used by students for an end-of-semester calculus exam.

Key words: Examinations; Revision; Phenomenography; Calculus

Introduction

In mathematics exams at Swinburne University of Technology, Australia, undergraduate students may bring with them a single, double-sided, page of written notes. It is hoped that, in the process of creating these “crib sheets”, students will revise effectively as they will have access to certain content of their choosing during the exam. There is also a belief that there will be a reduction in anxiety and the amount of rote learning of formulae and procedures required of students, who are then freed up to focus on deeper conceptual understanding of material.

Literature

When crib sheet exams are referred to in the literature, it is typically within the contexts of exam anxiety and exam performance. When considering the effect on exam anxiety, the majority of authors note that the use of crib sheets is effective in reducing anxiety (Butler & Crouch, 2011; Erbe, 2007; Janick, 1990; Weimer, 1989). Dickson and Miller’s (2005) study with students in an undergraduate child development course found that students’ prior beliefs about anxiety and subsequent reflections may not align: 80% believed that by using a crib sheet they would feel less anxious, but only 40% stated after the exam that they had done so.

In terms of exam performance, Dorsel and Cundiff (1979) noted that there is a link to the note-taking literature, in which authors such as Rickards and Friedman (1978) describe an ‘external storage hypothesis’ which implies that students will do better because they have access to more information during the exam, and an ‘encoding hypothesis’ that suggests the process of creating crib sheets allows students to organize their thinking. In line with these hypotheses, Gharib, Phillips, and Noelle (2012) found that psychology undergraduates scored significantly better on crib sheet exams than closed book, but also that they did better still on open book tests. Similar improvements were seen with Economics students (Wachsman, 2002) and students in a teaching course (Skidmore & Aagaard, 2004). In contrast, other authors have found no significant effect on performance (e.g. Dickson & Miller, 2005, and the statistics undergraduate students in Gharib et al.’s 2012 study). Such results do vary with the type of assessment, with improvements stronger for recall-based tests. Dickson and Bauer (2008) investigated the encoding hypothesis, and found that construction of crib sheets did not improve performance when students did not have access to their crib sheets. A meta-analysis of quantitative studies on crib sheets and open book exams by Lawin, Gorman, and Larwin (2013) found that overall, there is a “substantially higher” effect size for studies

comparing student performance between crib sheet exams and closed-book exams, compared with those studies that had compared open-book and closed-book exams.

Less has been researched in the context of undergraduate mathematics. It is often argued that students consider mathematics to be primarily based on surface procedures (Crawford, Gordon, Nicholas, & Prosser, 1994; Frank, 1988; Garofalo, 1989). We might expect from the external storage hypothesis that crib sheets will boost performance in exams that require such procedural understanding. There is, however, growing evidence that crib sheets encourage reliance on procedural surface-level understanding of topics (Dickson & Bauer, 2008), dependence on the crib sheets (Funk & Dickson, 2011), and a “search” mentality when stuck on a problem (Burns, 2014). Whitley (1996) proposed a null effect: having more information is counter-acted by a belief from students that they need to understand it less well.

There is a need therefore to investigate crib sheet use in the context of undergraduate mathematics. We begin to do this here by first exploring the content on students’ crib sheets. A limited amount of work has been done in this area outside of mathematics. Ludorf and Clark (2014) measured the quality of psychology undergraduates’ crib sheets subjectively on scales measured 1-5 for *Overall quality*, *Verbal process information*, *Numeric process information*, *Density*, *Organization*, *Use of color*, and *Date of submission* (it is not clear from the paper how each scale was constructed, or how they compare). They found a positive correlation between the quality of a crib sheet, and performance in an exam. Content of the crib sheets produced by undergraduates on a programming course was encoded by de Raadt (2012). This took the form of binary indicators in the themes of *Layout* and *Content*, which were broken down into sub-themes: *Density/Organization/Ordering* and *Examples [of code]/Abstract representations [diagrams]/Sample Answers/Duplication*. Better exam performance was linked to those students whose crib sheets had a similar order to the course, who gave abstract representations, whereas indicators of poor performance were giving examples of code and sample answers. Our preliminary coding of our data from an undergraduate calculus class echoes de Raadt’s broad themes, although inherent differences between the disciplines result in several differences at a more detailed level.

Methodology

This report presents preliminary results from the first of a four-stage research project. It addresses the questions “what do students choose to include on crib sheets?” and “how is this information presented?” Our data is crib sheets produced (and used) by students for a final unit examination in a first calculus course for non-mathematics majors.

Underlying our work is an assumption that a student’s crib sheet represents that student’s awareness of a course. More specifically, we believe crib sheets are a good indicator of the content students consider important for an exam and the material with which they feel least confident, both presented in a way that is intended to be helpful in an exam. We acknowledge that material already committed to memory may not be included on crib sheets, but we note that authors suggest that students aim to fill up their sheets completely (Erbe, 2007; Visco, Swaminathan, Zagumny, & Anthony, 2007). We have framed the four-stage project is within the interpretivist methodology of Phenomenography (Marton & Booth, 1997; Marton & Saljo, 2005), with an aim to explore students’ use of crib sheets as a lens indicating their awareness of the course content. The results presented here from the first stage of the project are categories of description of the salient features of our students’ crib sheets. We subscribe to the principle of Variation Theory (Runesson, 1999; Watson & Mason, 2006), in that we believe that if students are exposed to and become comfortable with many facets of crib sheet construction and content, they will be able to produce better, more effective crib sheets.

Our preliminary analysis is based on both authors independently open-coding salient properties of 30 crib sheets. The authors then discussed their codings, and constructed

Table 1

Dimensions of variation emerging from the preliminary coding exercise

Theme	Category of description	Types of difference
Layout-based	Density	Font size, Amount of white space, Location of white space
	Emphasis	Coloring, Boxing, Headings, Linearity, Box outs, Starring, Separation
	Sheet structure	Course Structure, Similarity structure, Neatness, Bullets, Orientation, Sub-division
Content-based	Examples	Worked solutions, Boundary examples, Sketches, Transferability of examples
	Representations	Brevity / Complexity, Calculator procedures, Fill in the gaps, Other languages
	Formulae	Listed, Grouped, In situ, Repetition of formulae sheet content
	Meta-content	Reminders, Messages, Thematic commentary, Arrows Indexing with color themes
	Correctness	Errors, Completeness

dimensions of variation, presented in Table 1. In the next stage of the project, we will examine all crib sheets from this class and also those from a different, more advanced course, in an attempt to describe the categories of variation as completely as possible, and to see if there are any differences between the groups. By the time this work is presented, we will have recorded a complete set of dimensions of variation for the crib sheets, and also recorded their occurrences and linkages between occurrences. Further stages of the project are planned, have received ethics clearance, and are described in more detail below.

Preliminary Results

Our preliminary themes and categories of description are listed and described in Table 1. We noted a distinction between the themes of content and layout, a distinction also made by de Raadt (2012). Due to the differences in subject and course, our categories of description were different to de Raadt's, and we note that our categories are rarely binary indicators.

In terms of layout, there were distinctions between density of text (i.e. font size), amount of white space (or gaps), and where white space was located. We also observed different techniques used to emphasize parts of their sheets: coloring, boxing, underlining. On some sheets these were present throughout, and on others only for key concepts (which is a link to the content-based categories of description). The structure of sheet layout also varied, with various methods to sub-divide space. In terms of content-based categories, there is a difference from de Raadt in that no students choose to include portions of code, but instead we saw many worked examples from lectures stated verbatim. The parts of these examples that were generalizable to the topic in question were seldom indicated and some contained copying errors. Different representations were used, with formulae statements being so ubiquitous that they were included as a sub-theme. A minority of students included content that was not directly from lectures and we labeled this meta-content.

Discussion

By taking the crib sheets as primary data, we have a snapshot of what students consider important to their exam performance. We do not know how the sheets were constructed, why particular layout and content were chosen, the relative importance of the content, or any links to anxiety or exam performance. This initial analysis has been necessary to address the gap in the literature of what students choose to include in crib sheets for undergraduate mathematics

exams. It also will allow us to ground further parts of this project with an appropriate coding structure, rather than one taken from the literature of a different discipline area.

With this in mind, for the remainder of the first stage of the project, we will assume that students considered everything on their sheets important, and draw the inference that certain layout properties on the sheet such as boxing, underlining, highlighting and the use of color indicate emphasized importance. For instance, although worked examples were commonplace on many sheets, indicating students found them an important part of the course, they were rarely given a status of emphasis. By the time this work is presented we will have a more detailed description for each dimension of variation for two different levels of students, we will have investigated which mathematical topics are associated to which categories of description, and also considered the associations between categories themselves.

The next stage in the project will be to explore the links between crib sheet content and exam performance (including total and by-question scores, and displayed misconceptions). We will also conduct research interviews with students, to see if our interpretations of the data fit student views on the construction of crib sheets. Both these parts of the study will be completed in the second half of 2015. Our overall aim with the project is to formulate guidance to give to students before they produce crib sheets, and to conduct a randomized trial to see whether such guidance brings a performance gain in examinations (and thus, we hope, understanding of the course content). As Visco et al. (2007) noted, there is seldom a social aspect to construction of crib sheets, and we hope that encouraging a dialogue will aid construction and therefore performance. Such a trial will take place in 2016.

Questions to consider:

1. What is the relationship between content included on a crib sheet, the perceived importance of such content, and a students' level of confidence with that material?
2. Do crib sheets promote surface-level procedural understanding of a topic, or do they help students prioritize deeper understanding by relegating procedural content to the sheet?

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