ASSESSMENT OF GRADUATE PROFILE ATTRIBUTES IN A STATISTICS CAPSTONE COURSE

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In 2019 the University of Auckland (UoA) introduced compulsory capstone courses for all undergraduates in the Faculty of Science in recognition that students required more support to transition from being a student of a discipline to a practitioner. One requirement of the science capstone courses was to provide a vehicle for students to demonstrate the attributes of the graduate profile. Many universities have established graduate profiles to provide clarity to students, staff, and employers alike about the qualities graduates from their institution should possess. This research sought to establish whether UoA graduate profile attributes could be demonstrated and assessed in a statistics capstone course. A framework to evaluate the demonstration of graduate attributes was developed, which along with some preliminary results is presented and discussed.

BACKGROUND

The Higher Education (HE) sector has experienced huge growth this century and the International Institute for Applied Systems Analysis (2016) predict growth to continue for the foreseeable future. The massification of HE has had major implications for the three main stakeholders: universities and other tertiary institutions, students, and employers. Universities have had to adapt to a larger and more diverse student cohort by increasing their range of courses and offering alternative modes of delivery. Employers have called for a greater emphasis on employability skills (Confederation of British Industry, 2015; Roberts, 2002). Students are remaining in HE longer believing that a bachelor's degree is no longer sufficient in today's job market (British Council, 2014). For students this means that they have higher student loans to repay and are consequently looking for higher salaries, which employers are reluctant to pay for recruits that many view as not yet equipped with the skills necessary for success in the workforce. To address such issues of employability and to create a point of difference for their graduates, the UoA introduced compulsory capstone courses for all Faculty of Science undergraduates in 2019, which meant they would be first taught in 2021. The argument for the implementation of capstones to improve employability and other factors is evidenced by extensive research (Hotaling, et al., 2012; Keller et al., 2011). A main requirement of the capstone course was to provide opportunities for students to demonstrate the UoA graduate profile attributes and to assess them. The UoA graduate profile has been in existence since 2003, but the Faculty of Science capstone courses are the first attempt to develop courses that directly assess such attributes.

THE PROBLEM

The UoA graduate profile has six attributes: Disciplinary Knowledge and Practice, Critical Thinking, Solution Seeking, Communication and Engagement, Independence and Integrity, and Social and Environmental Responsibilities (Figure 1).

Figure 1. Graduate profile attributes

In S. A. Peters, L. Zapata-Cardona, F. Bonafini, & A. Fan (Eds.), *Bridging the Gap: Empowering & Educating Today's Learners in Statistics. Proceedings of the 11th International Conference on Teaching Statistics (ICOTS11 2022), Rosario, Argentina.* International Association for Statistical Education. iase-web.org

Developers of capstone courses were given few guidelines; graduate profile attributes had to be assessed but not via a formal exam and had to include elements within the attributes such as opportunities for integrative learning within the Solution Seeking attribute, opportunities for self-directed learning within the Independence and Integrity attribute, teamwork tasks and oral and written communication tasks within the Communication and Engagement attribute, and reflection within the Critical Thinking attribute.

The work described in this paper is part of a larger study for which the main research question is: Which UoA graduate profile attributes are demonstrated by students enrolled in a statistics capstone course, and to what level? To answer this research question, data was collected from two cohorts of students enrolled in a statistics capstone course. The data included all items of course work submitted by students who had agreed to participate in the research. Assessment tasks were varied and included individual and team tasks, presentations, peer evaluations, coding tasks, data visualisations, and reflective activities. A framework or rubric was needed to analyse this data and to answer the research question. Initially, I had hoped that an existing framework could be found for the analysis, but trials of an established rubric in a pilot study demonstrated that for this research question, any generic rubric would require interpretation for the discipline of statistics (Kensington-Miller et al., 2018). Thus it became necessary to create a synthesised framework based on the literature and graduate profile attributes. In this paper the development of the framework and some attributes are discussed along with some student examples for the Communication and Engagement attribute.

THEORETICAL FRAMEWORK

The theory of cognitive apprenticeship (Collins et al.,1989) was selected as the main lens for this research. Although other established educational theories could have been utilised, the theory of cognitive apprenticeship embraced more closely the aims of capstone courses by offering a framework that describes a student's journey from novice towards expert status (Figure 2). This theory suggests that certain pedagogical approaches support a student's transition from novice to expert, such as modelling, coaching, scaffolding with fading, articulating, reflecting, and exploring. The type of framework provided by this theoretical approach appeared to offer both guidance to lecturers involved in developing capstone courses as well as an indicator of what might be required of students to demonstrate capstone level competence in each of the graduate profile attributes.

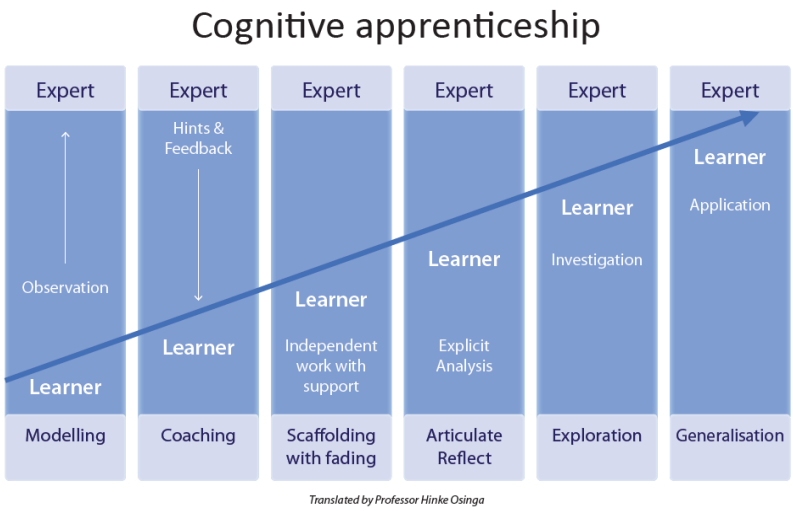

Figure 2. Cognitive apprenticeship theory pedagogical approaches. Source: https://commons.wikimedia.org/wiki/File:Cognitive_apprenticeship-1509489159.jpg

METHODOLOGY

Instruments used in this research were initially tested on a cohort of students enrolled in a capstone-like Geography course. To answer the main research question, data was collected from two student cohorts enrolled in a statistics capstone course. The first cohort were enrolled in Semester 1, 2021, and the second cohort in Semester 2, 2021. This paper draws on data from the first cohort only,

which consisted of 10 students who all agreed to participate in the research. Students also completed pre- and post-course surveys, and some participated in a focus group. The two lecturers completed pre- and post-course surveys.

The analysis approach adopted was closely aligned with template analysis (King, 1998). Central to the approach of template analysis is the development of a coding template or codebook. Template analysis was specifically developed to handle any type of textual data, which was well suited to the analysis of the main source of data—coursework submissions that were largely textual. One of the attractions of this approach for this research was the ability to include a priori codes, i.e., codes that are specified before data analysis takes place (Crabtree & Miller, 1999). In this research the a priori codes related to the graduate profile attributes. Such an approach differs from many other qualitative data analysis methods as it represents a deductive ('top-down') rather than an inductive ('bottom up') or data-driven approach. Consequently, rather than themes emerging from the data, in this research the themes already existed—the six attributes of the Graduate Profile. Thus the aim was to establish evidence of those themes in the data, rather than establish what themes existed. Data was analysed using NVivo software, which allows the handling and coding of textual data, images, etc.

DEVELOPMENT OF SYNTHESISED FRAMEWORK

In the pilot study the VALUES rubrics (Association of American Colleges and Universities, 2009) were considered because they appeared to align well with the UoA graduate profile and importantly provided a development framework, which illustrated how attributes might be demonstrated at four different levels: novice, developing, extended developing, and capstone. There are sixteen VALUES rubrics and each one is broken down into five or six sub-categories. I coded data from course work submitted by students in a Geography capstone-like course against this framework and found that using all sixteen rubrics tended to be repetitive and that certain attributes, which were of particular importance to the discipline of statistics, were not highlighted. Also, several universities who had used the VALUES rubrics to help evaluate their own programmes (Clark & Eynon, 2012) normally selected just one or two rubrics as their focus. Given the results from the pilot and Kensington-Miller et al.'s (2018) direction to interpret graduate profile attributes within a discipline, I decided to create my own synthesised framework to evaluate demonstration of the UoA graduate profile attributes; this synthesized framework would draw on the VALUES rubrics but also other frameworks and guidelines that related directly to the discipline of statistics.

To construct the synthesised framework, I utilised the structure of the VALUES rubrics, that is, each attribute and sub-attribute contained the same four developmental levels. The distinctions between each level of the VALUES rubrics were also retained, albeit reworded to highlight differences important to the discipline of statistics. To assist in the interpretation of the generic UoA graduate profile in the discipline of statistics, I drew on the American Statistical Association (ASA) guidelines for undergraduate programs in statistical science (2014). These guidelines included specific statistical skills such as data visualisations, ability to deal with messy data, formulation of good questions, and ability to interact and communicate with a variety of clients and collaborators as well as communicate results both written and orally in a manner that is appropriate to different audiences. Additionally, I incorporated the four dimensions of the statistical thinking framework developed by Wild and Pfannkuch (1999), noting particularly, Dimension 4—the dispositions required for statistical thinking, which included scepticism, imagination, curiosity, and perseverance to name a few.

The ASA guidelines, in line with the graduate profile attribute, Communication and Engagement, identified communication as part of statistical practice. In the synthesised framework this attribute was broken down into three different areas: oral communication, written communication, and communication within a team. For oral communication, two aspects captured in the framework were delivery of the central message and use of data visualisations. Table 1 shows these two aspects and how the developmental levels were differentiated.

PRELIMINARY RESULTS

Graduate Profile Attribute—Communication

Three communication assessment examples are presented along with the level demonstrated. One task required students to prepare an oral presentation for a secondary school audience on a statistical concept using data visualisations. One student chose principal component analysis and

created an interactive visualisation to illustrate his point that in principal component analysis, we are striving for the biggest variance and the smallest error. Three screenshots from this interactive graphic are shown in Figure 3. This mesmerising interactive graphic was an excellent choice for the audience and was coded at the capstone level of oral communication for the two aspects in Table 1.

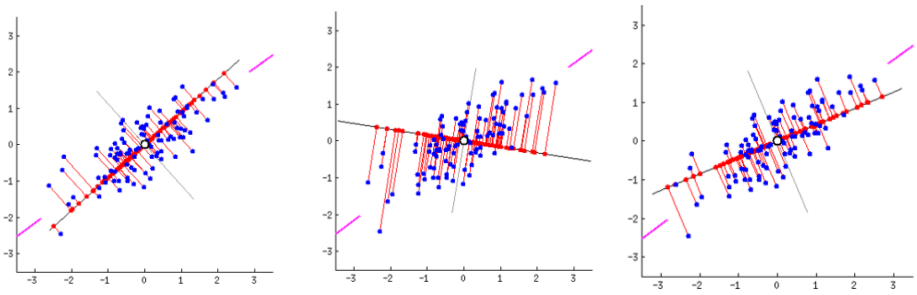

Figure 3. Interactive graphic used in oral presentation about principal component analysis

Another task required students to write a 'Very Simple Explanation' of a statistical model or concept using only the 1000 most common words in the English language, which was assessed against written communication in the framework. One student chose to describe '*p*-value' and wrote:

> The smaller the *p*-value, the more certain we would be to say our idea is wrong. Most of the time, if the *p*-value is less than 0.05, we would say that the idea is wrong. If the *p*-value is greater than 0.05, it suggests that our idea is true.

Table 1. Developmental levels of two aspects of oral communication in the synthesised framework

Level	Central Message	Use of Data Visualisations
Novice	Central message can be deduced, but is not explicitly stated in the presentation.	At least one visualisation created but inappropriate either because of audience or context. Visualisation does not add to audience's understanding.
Developing	Central message is basically understandable but is not often repeated and is not memorable.	2–3 visualisations created that are appropriate to audience and relevant to context, but do not all add to audience's understanding.
Extended Developing	Central message is clear and consistent with the supporting material.	3–4 creative visualisations produced that are appropriate for the audience and help to improve understanding of the data.
Capstone	Central message is compelling (precisely stated, appropriately repeated, memorable, and strongly supported).	Transnumerative thinking used to create visualisations from appropriate variety of information sources that will significantly improve the audience's understanding of the data.

The statement was coded at an extended developing level, as the student failed to explain that a large *p*-value does not suggest that the null hypothesis is correct, it simply provides evidence against the null hypothesis. Several of these third-year students demonstrated similar misconceptions about *p*-values, and many regarded the 0.05 value as an absolute threshold rather than a guide value.

Data visualisations are an important part of communication in statistics, and in this course students frequently produced visualisations to support an oral presentation or to illustrate results in a report. One of the very first assessments required student teams to produce a visualisation using data that is text only. The source of the text data was responses to an online survey completed by all students about their sentiments towards the capstone at the very start of the course. Figure 4 shows one team's response, which was coded at the capstone level for the use of data visualisations aspect (Table 1) and for software and coding skills, an aspect in the Disciplinary Knowledge and Practice attribute.

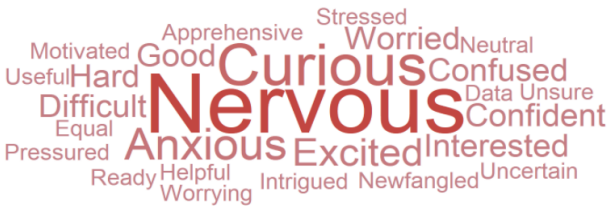

Figure 4. Graphic produced by a student team in statistics capstone course

Fair assessment for individuals based on a teamwork can be challenging but was pragmatically handled by giving this to students as a task. Teams had to determine an individual task score based on the overall team score and their peer-assessment scores, which was a value between 1 and 5. Teams presented their schemes for assessing teamwork and then the class voted on which scheme should be adopted for the course. The accepted team's scheme rewarded students whom their peers had rated above 2.5 while disincentivising a small number of students from doing all the work to maximise their peer score. The technical description of their method was:

$$fY\ Z(x) = \begin{cases} (x/2.5) \cdot y & \text{if } x < 2.5 \\ y & \text{if } 2.5 \leq x \leq 5 \text{ and } z < 0.5 \\ ((0.1 \cdot z) + 1) \cdot y & \text{if } 2.5 \leq x \leq 5 \text{ and } z \geq 0.5 \end{cases}$$

$$x = \text{individual score } \{x \in \mathbb{R} \mid [1, 5]\}$$

$$y = \text{group grade } \{y \in \mathbb{R} \mid [0, 100]\}$$

$$z = \text{proportion of non} - \text{performers } \{z \in \mathbb{R} \mid [0, 1]$$

Graduate Profile Attributes—Solution Seeking and Critical Thinking

Students were considered to have demonstrated the attribute of Solution Seeking if they correctly applied a suggested statistical technique. However, in the capstone course, students often had to select an appropriate statistical technique for their data analysis, which research has shown is more challenging for students as a far transfer skill (Barnett & Ceci, 2002; Lightner et al., 2008; Salomon & Perkins, 1989). Typically, undergraduate courses provide ample practice for students to demonstrate near transfer skills, where the technique to be used is specified. In today's everchanging world, it is far transfer skills that are critical for today's graduates to develop, and thus it is particularly important that capstone courses provide students with the opportunity to practice such skills (Huber & Hutchings, 2004). This capstone course offered students several tasks that required far transfer skills. Early in the course, prompts were provided to encourage this level of thinking. Tasks towards the end of the course included no such prompts. For example, one task required teams to identify which teachers in a dataset of test results had been manipulating scores to improve pass rates. The capstone level for the Critical Thinking attribute required students to articulate and justify why a particular solution method was chosen; this was demonstrated by one group, who included in their report on manipulative teachers a clear statement of assumptions made, a description of methods considered, justification of why a particular method was selected, and details on the strengths and weaknesses of their analysis.

Results from the first cohort of the statistics capstone course showed that students had demonstrated all six of the graduate profile attributes. However, students in focus groups felt they were given few opportunities to demonstrate the Social and Environmental Responsibilities attribute. This attribute requires students to acknowledge Māori world views and the historic place of the Treaty of Waitangi as well as international political, social, cultural, environmental, economic, and historical perspectives. The students' observations were correct, as fewer opportunities were given to demonstrate this attribute than any of the other five attributes.

CONCLUSION

The framework against which student course work was evaluated has provided evidence to confirm that graduate profile attributes can be demonstrated and assessed within a statistics capstone course. The development and use of the framework rubrics confirmed Kensington-Miller et al.'s (2018) contention that it was necessary to interpret the graduate profile attributes as they applied to the practice of the statistics discipline and that the rubrics could be used to assess students' developmental levels within each attribute (cf. Clark & Eynon, 2012). The UoA graduate profile has similarities with

other university profiles and as such the framework could prove useful to other statistics capstone educators as a resource to identify areas in their curricula that might require further development.

Analysis of the second cohort, involving almost 100 students, is ongoing. Due to the pandemic, most of the course was conducted online, so it will be interesting to see if the increased numbers and/or the mode of delivery affected the demonstration of attributes. Encouraging the development of attributes described in graduate profiles is an important way that tertiary institutions can support students to make the transition to becoming confident practitioners within their discipline.

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