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Hossana Twinomurinzi
University of Johannesburg, twinoh@gmail.com

Siyabonga Mhlongo
University of Johannesburg, siyabongam@uj.ac.za

Kelvin J. Bwalya
University of Johannesburg

Tebogo Bokaba
University of Johannesburg, tbokaba@uj.ac.za

Steven Mbeya
University of Johannesburg, smbeya@uj.ac.za

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Multidisciplinarity in Data Science Curricula

Hossana Twinomurinzi, University of Johannesburg, twinoh@gmail.com
Siyabonga Mhlongo, University of Johannesburg, siyabongam@uj.ac.za
Kelvin J. Bwalya, University of Johannesburg, kbwalya@uj.ac.za
Tebogo Bokaba, University of Johannesburg, tbokaba@uj.ac.za
Steven Mbeya, University of Johannesburg, smbeya@uj.ac.za

ABSTRACT

This paper sought to identify and compare disciplinary emphases in data science curricula across South Africa's 26 public universities using a website scoping review method. The key findings reveal that only 12 of the 26 universities offer data science programmes that are publicly accessible on their websites. Of those 12, only 5 offer data science at the undergraduate level, and these undergraduate programmes are *objectified* (entirely leaning) to the science, technology, engineering, and mathematics (STEM) disciplines. Only seven of the universities offer a few non-STEM subjects with only one offering more non-STEM subjects compared to STEM subjects. The implications are that curricula of data science, which is multidisciplinary in nature, are more likely to inherit the STEM curricula challenges. The resultant impact will therefore likely extend to skills, future careers, and employment, in view of the growing demand for data scientists amid the unemployment challenges. It is recommended that intentional efforts must be made to necessarily *ideologise* non-STEM disciplines into data science curricula in South Africa, that is, to deeply embed societal contexts into data science curricula.

Keywords

Data science, curricula, South Africa, multidisciplinarity, public universities.

INTRODUCTION

Data science (DS) is an emerging multidisciplinary area that has found application in all disciplines from STEM to non-STEM. Current debates on DS suggest an existence of divergent views on whether DS should be considered a field or discipline. While one school of thought endorses each of the DS domains forming part of a discipline, another argues that DS merits its own unique curricula (Wilkerson & Polman, 2020). There are therefore differences in how DS curricula are structured within academic and training institutions, and professional DS bodies.

Although curriculum activities relating to design and development are demanding, they are critical in the context of multidisciplinarity and redress, especially in countries such as South Africa which continues to reel from the history of separate education (Chisholm, 2003). Arduousness is one of the reasons why many curricula remain the same even years after they have ceased to be relevant.

In this paper, we focus on the disciplinary emphases of DS curricula in South Africa's 26 public universities. Primarily, we seek to answer the question: *"What is the disciplinary emphasis of data science curricula in South Africa's public universities?"*

The remainder of the paper is structured as follows: the next section briefly reviews extant literature on DS and curriculum design. After presenting the method adopted for this scoping review, the section that follows presents findings and analyses of the research before closing with a conclusion section.

LITERATURE REVIEW

Data Science

DS is the art and science of extracting meaning from data. While the 'art' aspect of DS comprises the context that shapes the *meaning* and formulates the contextual questions that need to be answered, the 'science' denotes the systematic and structural process followed to extract the meaning from the data. This means that the same data can result in multiple insights that are dependent on the contextual *meaning*.

CRISP-DM (CRoss-Industry Standard Process for Data Mining) was established in 1996 and remains the most widely-used DS methodology and process model (Figure 1).

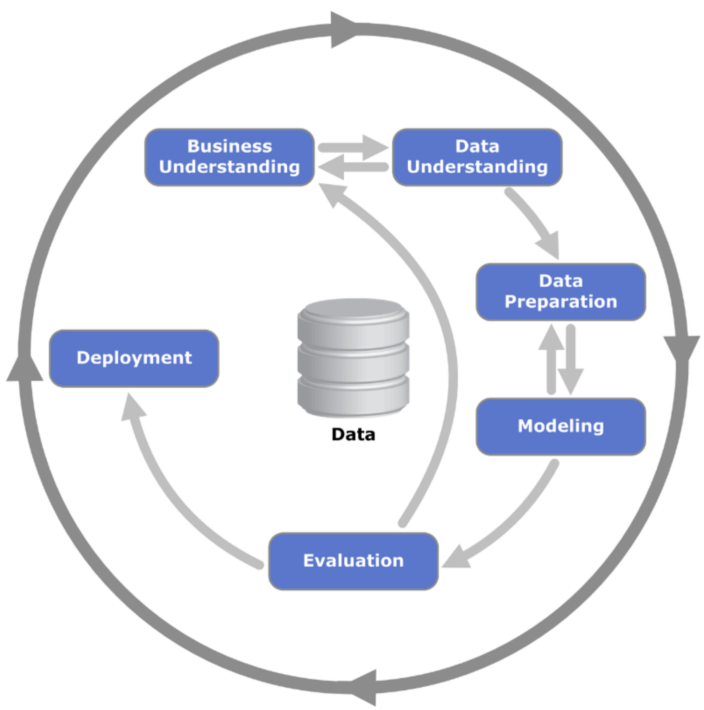

Figure 1: The CRISP-DM methodology (Source: Shearer, 2020)

The six steps of CRISP-DM are: (i) business understanding, which focuses on understanding the business objectives and requirements; (ii) data understanding, wherein the available data relating to the business objectives are gathered and understood, and hypotheses are created; (iii) data preparation, during which the data are processed into a final dataset that can be fed into modelling tools; (iv) modelling, which involves the science of establishing patterns in the data, and accepting or rejecting the hypotheses; (v) evaluation, wherein accuracy and validity of the results are ensured; and (vi) the final step of deployment, wherein the useful models are deployed and practicalised.

In the next section, we describe some fundamentals of curricula.

Fundamentals of Curriculum

There are two primary definitions of *"a curriculum"* (Grant, 2018; Hass, 1987; Schubert, 1986; Tanner & Tanner, 1980), namely: (i) a tangible set of things, and (ii) an ideological concept deeply embedded in societal settings. Schubert (1986) cautions against objectifying a curriculum as it "reduces its richness and rules out presentation of certain key conceptualizations that are essential to an understanding of the field" (p. 26). The latter definition considers the learning experiences, goals and outcomes, the construction and reconstruction of knowledge, as well as acquisition of competence. The realisation of the latter approach to curricula incorporates the philosophical, historical, psychological, and social nuances required in any society (Ornstein & Hunkins, 2018). Curriculum design and development are therefore complex processes that deal with the nature and arrangement of the objectives, content, learning experiences, and evaluation of content. The design process rests on philosophical, political, social, and cultural dispositions (Grant, 2018, p. 75) while the development process is dynamic, and grounded on current societal and cultural demands (Alsubaie, 2016).

Curriculum implementation puts the design and development results into action in a learning environment, often emphasising speed and expediency. Implementation is therefore influenced by the educators' internal belief systems, and the presence and vastness of a support network (Roehrig et al., 2007). Practically, implementation is a fully-fledged change process that requires change management (Ornstein & Hunkins, 2018; Tichnor-Wagner, 2019).

Curriculum evaluation is a necessary undertaking which seeks to "judge the merits and deficiencies of a particular educational program produced and administered in a certain organizational and social setting" (Lewy, 1973, p. 8). Evaluation is intricately bound to the philosophical perspectives of the curriculum design, development, and implementation processes, and is centred on the actions of both the educator and the student (Ornstein & Hunkins, 2018).

METHOD

Review methodologies rely on the question to be addressed (Gough, 2015; Snilstveit et al., 2012). Scoping reviews are particularly helpful when an overview or map of the evidence is required as opposed to a critical review and synthesis (Munn et al., 2018). We therefore adopted the scoping review of Arksey and O'Malley (2005) to examine the disciplinary emphases of DS curricula in the 26 South African public universities.

Stage 1: Identifying the Research Question

This entry stage is concerned with identifying the research question which for this paper is: *"What is the disciplinary emphasis of data science curricula in South African public universities?"*

Stage 2: Identifying Relevant Studies

We comprehensively identified the relevant studies, documents, and other information sources using a website scoping review method. In this regard, information for collating this scoping review was generated by using the Google search engine on each of the university websites. Specifically, the search string that was used for the above-mentioned search engine was as follows: `"data science" site:domain-of-university` (for example: `"data science" site:uj.ac.za`).

Stage 3: Study Selection

We applied inclusion and exclusion criteria to sift through the documents identified and collected during the preceding stage. Information was included if it related to: (i) a stand-alone DS programme; or (ii) DS being embedded in other programmes (but not necessarily as a stand-alone or a major). This was applicable to both undergraduate (UG) and postgraduate (PG) study levels.

Stage 4: Charting the Data

This stage of the scoping review approach is adopted from Ritchie and Spencer (1994) and it involves a technique for abstracting, synthesising, and interpreting data. It often involves making use of a “data charting form” to chart the information extracted from the data, and follows a “narrative review” or a “descriptive analytical” method to extract contextual or process-oriented information from the data (Levac et al., 2010).

Stage 5: Collating, Summarising, and Reporting the Results

This is the final stage of the scoping review approach and it is primarily concerned with reporting the results of the research study. This stage draws from the information charted during the preceding step and is aimed at applying meaning to the data and correlate it to the research aims. The next section expands on this stage of the scoping review approach for this research study.

RESULTS AND ANALYSIS

Table 1 presents the results of the scoping review. The scoping exercise revealed that only 12 of the 26 universities offer data science programmes that are publicly accessible on their websites. Of those 12, only 5 offer data science at the UG level, most of which were created by fusing various subjects from different STEM disciplines into a single DS programme. The *objectified* curricula approach does not deeply engage with the *ideological* demands of curriculum design and development. In rushing past the murky demands of enriching each of the subjects with the contextual needs, the richness of a truly multidisciplinary DS programme, enriched with non-STEM content, could be lost (Nicolescu, 2014).

Apart from the DS-focused Master of Science and Master of Arts in e-Science degrees offered by 6 universities (University of Venda, University of the Witwatersrand, University of Pretoria, Sol Plaatje University, University of Limpopo and North-West University), there is no standardised DS curriculum offered in South Africa. Most of the DS programmes being offered have not been evaluated because they are still less than 4 years old. It will therefore be interesting to see how future curriculum evaluations will pan out.

#	University	PG	UG	non-STEM	Research	Province
1	North-West University	PG	UG	-	Yes	North-West
2	Sol Plaatje University	PG	UG	-	Yes	Northern Cape
3	Stellenbosch University	PG	UG	-	Yes	Western Cape
4	University of Cape Town	PG	-	Yes	Yes	Western Cape
5	University of Johannesburg	PG	-	Yes	Yes	Gauteng
6	University of KwaZulu-Natal	PG	-	Yes	Yes	KwaZulu-Natal
7	University of Limpopo	PG	-	-	-	Limpopo
8	University of Pretoria	PG	UG	Yes	Yes	Gauteng
9	University of the Free State	PG	UG	Yes	Yes	Free State
10	University of the Western Cape	PG	-	Yes	Yes	Western Cape
11	University of Venda	PG	-	-	-	Limpopo
12	University of the Witwatersrand	PG	-	Yes	Yes	Gauteng

Table 1: Public universities offering DS programmes (Source: Authors)

At the time of collating information for this scoping review, the universities located in the provinces of Eastern Cape and Mpumalanga did not have any active DS programmes. These two provinces have the highest and third highest unemployment rates in South Africa, 47.4% and 37.5% respectively (Stats SA, 2021). This means that opportunities for employment in DS are lost, considering that DS is one of the fastest growing skills in demand.

The emphasis on DS PG programmes (see Table 1) means that more emphasis is placed on specialisation as opposed to the grounding skills required at UG level. While both competencies are necessary—that is, grounding through UG skills versus specialisation from PG skills—there is a greater demand for data scientists who understand the fundamentals of DS.

CONCLUSIONS

The paper sought to understand the disciplinary emphases of DS curricula in the 26 public South African universities, that is, the extent to which DS curricula account for STEM or non-STEM content. It has emerged that the public universities have largely avoided the *ideological* demand in the curriculum design and development of DS offerings. Instead, the emphasis has been on the *objectification* of DS from the STEM disciplines which has placed little to no demand on the contextual needs of society but has focused on quickly incorporating existing STEM subjects into DS. This means that the epistemological and curricula dangers that accompany STEM subjects are likely to carry over to DS curricula, for example, the challenge of limited skills in STEM is likely to carry over to DS as well because it is primarily based on STEM curricula. There have been increasing calls to improve STEM curricula and make it more accessible. Examples of this include the popular "calculus reform" agenda (Ferrini-Mundy & Graham, 1991).

The emphases on PG curricula means that there is not much emphasis placed on developing primary and grounding skills in DS, but rather on specialist skills at the PG level, once again taking mainly from the STEM disciplines. The accompanying danger therefore carries through to employment opportunities. The implications of the above STEM and specialist disciplinary emphases are that the contextual needs of

South Africa (unemployment, poverty, and inequality) are therefore ignored. DS needs to engage with these contextual needs in order to find solutions for these pressing challenges. The rich insights and patterns that DS brings would invariably add value by finding new solutions to the pressing challenges.

The recency of DS curricula means that curriculum evaluation has not been carried out yet. However, the demand for data scientists might call for the shortening of the time within which curriculum evaluation of DS programmes is undertaken. Unfortunately, there are few agreed upon DS standards—locally and globally.

One of the limitations of the paper is that much of the information used in this scoping review was sourced from websites of the targeted academic institution. An obvious limitation that comes with this type of methodological approach is that there is a risk of important extant information not being incorporated into the website of the academic institutions that were sampled. Another limitation is the existence of various naming conventions of DS such as artificial intelligence, data analytics, data mining, and business analytics. It is possible that information pertaining to DS was missed simply because the "correct" search name was not used. To this end, future research should consider incorporating other data collection methods such as interviews.

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