Curriculum mapping for health professions education: A typology

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Abstract

Introduction: Across higher education, curriculum mapping has attracted great interest, partly driven by the need to map graduate competencies to learning and assessment for quality assurance and accreditation. Other drivers have included the need to: a) provide tools for curriculum design and renewal, b) improve communication amongst teachers and curriculum developers and c) support learning by informing students about the scope and sequence of their programs. Those embarking on curriculum mapping have sought clarification about what elements of the curriculum should be mapped, how to develop their own map or whether they should adopt externally available products. During our combined experience of mapping six different medical programs over the course of 15 years, we have frequently sought answers to these questions. However, due to the many and varying types of curriculum maps and curriculum-mapping processes that are described in the literature, answers have not been readily forthcoming.

Methods: We conducted a comprehensive review of the higher education—including health professions—literature to develop a four-dimensional typology for curriculum maps, which details features related to their purpose, product, process and display. The typology was validated by testing the parameters against six curriculum maps from medical schools around Australia.

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Results: Using a synthesis of 265 higher education publications, we created a structured framework and common language around the four dimensions of curriculum mapping.

Discussion: The typology can be used by health professions educators to make key decisions about the many curriculum map options available.

Keywords: curriculum; maps; information management; educational technology; education; learning; teaching; organization and administration; health professions; professional

Introduction

In the past 10 to 15 years, higher education has become increasingly involved in curriculum mapping (Bruinsma & Jansen, 2007; Decker et al., 2006; Figueroa et al., 2015; Harden, 2001; Oliver, 2013; Uchiyama & Radin, 2009). Those embarking on this process, often in the context of compliance and quality assurance or curriculum renewal, may seek clarification from the literature about what a curriculum map is, how it may be achieved, who will use it and for what purpose. However, this literature can be confusing, as many different types of curriculum maps, mapping approaches and mapping systems are described. Depending on variables such as the intended end-users, the type of educational program being mapped, the curriculum elements captured, the mapping processes adopted and the display platforms used, the functions and capabilities of curriculum maps can vary considerably. The lack of a clear framework and descriptors for such variables adds to the challenge of distinguishing and choosing between different types of maps. Adding to this complexity, the mapping literature spans the continuum of education from primary to tertiary and encompasses many academic disciplines. Three curriculum map models commonly cited in the literature are those by English (1978, 1980, 2010) and H. H. Jacobs (1997, 2000, 2004), both of which originated from primary/secondary education, and Harden (2001), which originated from medical education.

A fourth model, which has emerged recently, is what we describe as the "competency map" model. This model has arisen from the ever-growing compliance and quality assurance demands in health professions education (Decker et al., 2006; Figueroa et al., 2015; Talbot et al., 2007) and in higher education in general (Gluga, Kay, & Lever, 2013; Gluga, Kay, Lister, & Lever, 2012; Lawson, Taylor, French et al., 2015; Lawson, Taylor, Herbert et al., 2013; Natoli et al., 2013; Oliver, 2013; Tariq et al., 2004). As noted by Azzam (2013), we are now in the "competency era".

Broadly speaking, the competency map and English (1978, 1980, 2010) models define the purpose of curriculum maps primarily as tools for auditing and quality control, to be used for curriculum administration and management. Moreover, English (1978, 1980, 2010) emphasises that the map should be of the taught curriculum. In contrast, H. H. Jacobs (1997, 2000, 2004) defines the purpose of a map as a communication and collaboration tool for teachers to develop, deliver and review the curriculum. Harden (2001), however, defines a curriculum map's purpose as a learning tool for students to identify what, when, where and how they can learn, as well as a tool for

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teachers, curriculum planners and administrators to develop, implement, evaluate and improve the curriculum. Hence, in Harden's model, the focus shifts from curriculum administrators and teachers to students as end-users.

There is considerable diversity in the tools used to document, organise and, ultimately, display curriculum maps. For example, while many medical programs use online curriculum maps that are driven in the background by a database application (Al-Eyd et al., 2018; Hege & Fischer, 2012; Olmos & Corrin, 2011; Spreckelsen et al., 2013; Steketee, 2015) and have used such systems for some time (Denny, Smithers, Armstrong, & Spickard, 2005; Denny, Smithers, Armstrong, & Spickard, 2003; Lee et al., 2003; Salas et al., 2003; Watson et al., 2007), other health professions and higher education disciplines use stand-alone maps developed using a text file or spreadsheet application (Baecher, 2012; Britten et al., 2014; Collins et al., 2017; Dintzner, Nemec, Tanzer, & Welch, 2015; Dintzner, Nemec, & Tanzer, 2016; Fraser & Thomas, 2013; Joyner, 2016; Kertesz, 2015; Matveev et al., 2010; Oliver, 2013; Perlin, 2011; Romkey & Bradbury, 2007; Zelenitsky et al., 2014).

As shown in the surveys conducted by Willett (2008) and by Piotrowski (2011), medical schools often build or acquire their own curriculum mapping and management systems to meet their program's specific needs. A major lesson learnt from the now redundant Curriculum Management and Information Tool (CurrMIT) used by medical schools in the US and Canada was that one system could not meet the curriculum management needs of almost 200 medical schools and their programs (Ellaway, Albright et al., 2014). A pertinent outcome of Willett's (2008) survey was his classification of electronic curriculum maps into four clusters based on various elements of curriculum.

Building on the work by Willett (2008) and by Oliver et al. (2010), Watson (2013) developed a simple four-dimensional typology that allowed the classification of a curriculum map according to its purpose, the curriculum components mapped, the process used to capture curriculum data and the software used to create and display the map. While useful, it was evident that there were multiple options and possibilities within Watson's four dimensions that needed more clarity. The present study, therefore, aimed to further refine Watson's typology and create a more comprehensive framework for systematically analysing and describing curriculum maps relevant to health professions curricula.

Methods

Our study proceeded in two iterative phases. Firstly, we conducted a comprehensive literature review to identify and analyse curriculum maps relevant to our study's key question, which was "What are the curriculum map options described in the literature in relation to the purpose, process, product and display of a map?" We used the findings from the literature review to revise and refine Watson's (2013) original typology. Secondly, we tested the revised typology against six curriculum maps used in medical programs in our own institutions. We wanted to determine if the typology was comprehensive enough for us to use it to define and describe our own curriculum maps, and to see if it could provide a means by which maps could be compared to one another—our own included. The feedback gathered from this testing phase was used

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to further refine the draft typology. The process of refining the typology was iterative and collaborative.

Search strategy

An initial literature search on curriculum mapping for all years up to mid-2012 (Watson, 2013) was extended to include publications from 2012 to July 2018. Search terms included "curriculum mapping" or "curriculum map*" or "curricular mapping" or "curric* map*" (with or without the * truncation symbol), or "curriculum management system".

The initial search also included combining the term "curriculum" with the term "map" or "mapping" or "management" or "analysis" or "administration" or "knowledge system" or "database", either by enclosing both terms in quotations or by using the Boolean operator "AND", depending on the functions available in specific bibliographic databases. The extended search omitted these combinations since the term "curriculum mapping" has become a prevalent keyword in bibliographic databases and by authors, and the term "curriculum management system" was used instead of the combination of single terms. The less common terms "curricular map" and "curricular mapping" were also included in the extended search.

The initial search strategy included all fields and all years up to 2012. The extended search included either all fields or, where possible, the article title, abstract or keyword fields only. By restricting our searches to these three fields, we reduced the number of irrelevant articles retrieved. All searches limited the language to English.

We interrogated databases in education, health sciences, information technology and multidisciplinary fields. These included JSTOR, Emerald Fulltext, ScienceDirect, MEDLINE Ovid, PubMed, EMBASE, CINHAL, IEEE Xplore, Inspec, Scopus and ProQuest Databases, including ERIC. When interrogating Google Scholar, we used its advanced search tool and narrowed the search to the exact phrase in the title of the article and excluded patents and citations, therefore reducing the number of irrelevant hits.

Bibliographic referencing software (EndNote Thomson Reuters™) was used to import, save and manage all search results. Our initial extended searches of "all fields" for the phrase "curriculum map", "curriculum mapping" or "curricular map" retrieved many irrelevant articles that required further scanning (e.g., of 377 articles retrieved only 261 were related to the topic). Hence, our remaining extended searches were restricted to searching the article title, abstract and/or keywords fields whenever possible.

The findings from the initial search (all years up to 2012) with those from the extended search (from 2012 to 2018) were then combined in one EndNote file. Duplicate references were deleted, and titles and abstracts were further scanned for relevance to the study. All of the articles were categorised according to educational stage (i.e., primary–secondary or higher education) and higher education discipline (i.e., health professions or other disciplines). The first author performed all literature searches and the initial review, selection and categorisation of publications in EndNote.

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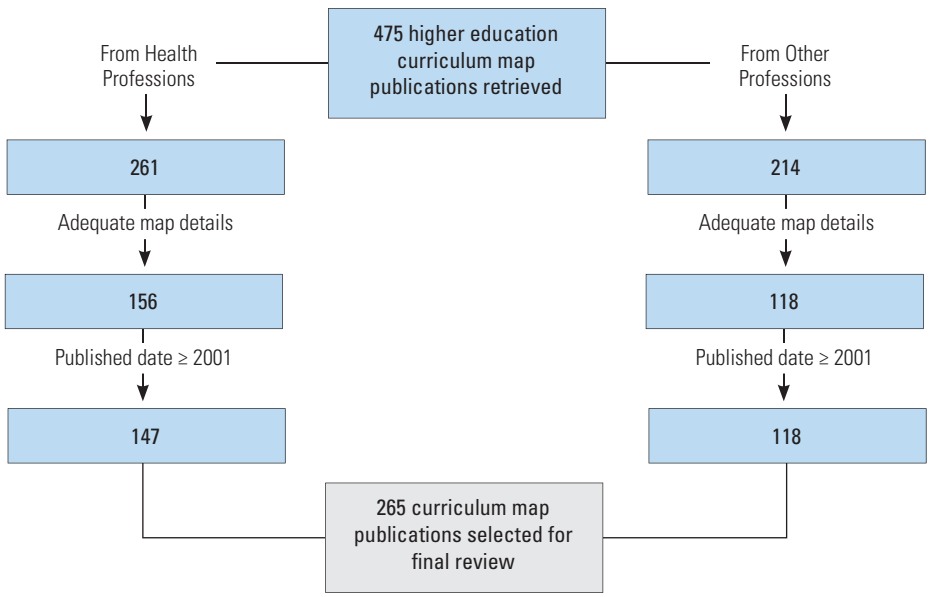
Search results and selection

The combined search results yielded a total of 588 unique publications on curriculum mapping, including peer-reviewed journal articles, conference publications, academic reports and books. Of these, 475 were of maps used in higher education, and 113 were of maps used in primary/secondary education. Our inclusion criteria for our final selection of publications were that the article: (i) covered maps used in health professions or higher education programs only, (ii) contained sufficient detail about a curriculum map to allow its classification and (iii) was published from 2001 onward, which was the year when Harden (2001) published his seminal article on curriculum mapping in medical education. Prior to Harden's paper, most curriculum map publications related to educational administrators' and teachers' use of maps in primary–secondary education. Despite their focus on primary/secondary education, key publications by English (1978, 1980, 2010) and H. H. Jacobs (1997, 2000, 2004) were included in the final results given their seminal work in the area of curriculum mapping. Higher education publications that either lacked map detail (e.g., conference abstracts or posters) or were not directly related to curriculum mapping were deleted. This resulted in a total of 265 higher education curriculum map publications, of which 147 were from the health professions and 118 from other disciplines. Figure 1 summarises the number of higher education publications on curriculum mapping that were retrieved, appraised and selected for final review.

Figure 1

Number of Higher Education Curriculum Map Publications Retrieved, Selected and Reviewed for All Years up to July 2018



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MS Excel™ was used to classify each of the 265 selected publications by year, type and relevance to this study and according to the key dimensions of each map and the higher education discipline it related to. In the category "health professions", we included medicine, nursing, dentistry, pharmacy, public health and various allied health professions, with all other disciplines being included as "other professions" (e.g., engineering, education, law, arts, etc.). All authors contributed to the review and classification of a set number of publications each, while the first author reviewed all 265 publications and the classification of articles by the other authors.

Developing the typology

The final selection of 265 publications were analysed for their relevance to mapping in higher education and health professions education and to better understand the four key dimensions of maps, namely their purpose (intended uses and end-users), product (curricular components mapped), process (actions used to capture curricular data) and display tools (systems used to support the process and produce the maps). These dimensions build upon Oliver et al.'s (2010) observations of what constitutes effective curriculum mapping and Willett's (2008) analysis of the various elements of a curriculum included in electronic maps of medical schools. Each of the four dimensions were expanded into a set of parameters to add definition and depth to its fundamental meaning and to cover the many issues that need to be considered at each stage of mapping. This process gave rise to a draft typology.

This draft typology was further refined using a validation process whereby each of the authors tested it against the curriculum map in their own medical programs. To enhance the transferability of our findings, these six maps were at different stages of design and development—from well-established comprehensive maps created for specific programs to planned maps under development to high-level maps using commercially-available applications. During the validation process, it was not always possible to define mutually exclusive options for each parameter in each dimension, so we aimed for an inclusive typology that would cover the practical issues that tend to arise during mapping.

Each dimension of the typology is described below. In discussing these findings, the term "course" is used to mean a unit or subject that forms part of a program of study for the award of a degree, and the term "discipline" refers to the body of knowledge of a degree program.

Results

Our findings are a synthesis of the 265 higher education publications reviewed to develop and elaborate the typology. Each dimension of the typology is described and supported with reference to the health professions literature, and the defining parameters are then presented in tabular form.

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Dimension one: Purpose *(intended uses and end-users)*

The primary purpose of curriculum maps varies from those developed principally to support curriculum administration and management (Britten et al., 2014; Collins et al., 2017; Ellaway, Albright et al., 2014; Figueroa et al., 2015; Fritze et al., 2018; Malone et al., 2015; Neiworth et al., 2014; Perlin, 2011; Talbot et al., 2007) to those with a more pedagogical focus, used to enhance teacher reflection (MacNeil & Hand, 2014; Steketee, 2015), communication and transparency (Al-Eyd et al., 2018; Lee et al., 2003; Wong & Roberts, 2007) and collaboration (MacNeil & Hand, 2014; Taleff et al., 2009; Watson et al., 2007), and to support the student learning experience (Balzer, Hautz et al., 2016; Kies, 2010; Komenda, Schwarz, Vaitsis et al., 2015; Lee et al., 2003; Plaza et al., 2007; Quirk, 2016; Steketee, 2015; Watson et al., 2007; Wijngaards-de Meij & Merx, 2018; Wong & Roberts, 2007; Zelenitsky et al., 2014). While a curriculum map could fulfil all these functions concurrently, the literature suggests that many maps have focused on one or a few end-users and uses, primarily curriculum designers and managers for administrative purposes. Increasingly, maps are being designed to help academic developers, teachers and students alike (Wijngaards-de Meij & Merx, 2018). Table 1 outlines the parameters and possible options evident for dimension one.

Table 1

Dimension One: Map Purpose (uses and users) Why map and for whom?				
Parameter	**Possible Options**			
Primary purpose	*Curriculum administration and management:* • auditing, accreditation, standards, workforce needs • curriculum planning, development, review, improvement • research	*Teaching (pedagogy):* • curriculum implementation, instruction, content delivery, alignment of outcomes, activities and assessments, gaps and overlaps, teacher guidance	*Learning (cognition):* • student learning, integration, revision, reflection, self-direction • access and download of content, student guidance, job preparedness	*Cultural and organisational change:* • curriculum governance processes, communication, collaboration, transparency, knowledge sharing, communities of practice
End-user	Academic administrators (curriculum managers, coordinator, planners, developers, committee members, researchers)	Teachers (course coordinators, lecturers, tutors, facilitators, clinical trainers, supervisors)	Students (junior, senior, pre-clinical, clinical) Trainees (postgraduate, clinical years)	External parties (accrediting bodies, professional organisations, workforce representatives, prospective students, the public)

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Dimension two: Product *(curricular components mapped)*

The product dimension refers to a map's level of granularity or detail. The map product can vary considerably depending on the type of curriculum mapped, the curricular content captured, the number of interconnected data sets included and the timeframe captured. Less granular maps capture generic graduate outcomes at the level of a course and may only include a select number of courses, topics or areas in an educational program (Britten et al., 2014; Collins et al., 2017; Keijsers et al., 2015; Malone et al., 2015; Narayanasamy et al., 2013; Robley et al., 2005; Taleff et al., 2009; van den Heuvel et al., 2017), two to three interconnected datasets (Figueroa et al., 2015; Malone et al., 2015; Neiworth et al., 2014) and, occasionally, whole programs from different institutions (Fritze et al., 2018). More granular maps capture all graduate outcomes (profession-specific and generic) at the level of individual learning and assessment activities in all courses of an education program (Balzer, Hautz et al., 2016; Dexter et al., 2012; Hege & Fischer, 2012; Hege et al., 2010; Kelley et al., 2008; Spreckelsen et al., 2013; Steketee, 2015; Watson et al., 2007; Zelenitsky et al., 2014) and often include topic lists and taxonomies (Balzer, Hautz et al., 2016; Dexter et al., 2012; Komenda, Schwarz, Švancara et al., 2015; Komenda, Víta et al., 2015; Stoddard & Brownfield, 2018), with six or more interconnected datasets. Some maps capture what is taught in the current calendar year (Keijsers et al., 2015; Narayanasamy et al., 2013; Plaza et al., 2007; Robley et al., 2005); some are retrospective and capture what was taught in the previous year (Britten et al., 2014; Malone et al., 2015; McGrath et al., 2006; Perlin, 2011; Talbot et al., 2007); others are prospective and capture what is taught in the following year (Madsen & Bell, 2012); and some with archiving systems can capture all three calendar phases (Watson, 2013). The educational setting captured can vary from activities based on campus (Keijsers et al., 2015; Watson et al., 2007), in the workplace (Balzer, Bietenbeck et al., 2015; Britten et al., 2014; Hatfield & Bangert, 2005; Neiworth et al., 2014; Olmos & Corrin, 2011; Sarkisian & Taylor, 2013; Wong & Roberts, 2007) and online (Ozdemir & Stebbins, 2015; Prince et al., 2011; Taleff et al., 2009). The educational programs can vary from undergraduate (Keijsers et al., 2015; Malone et al., 2015; Plaza et al., 2007) to postgraduate and traineeships (Britten et al., 2014; Prince et al., 2011; van den Heuvel et al., 2017; Wong & Roberts, 2007). Curriculum maps may cover the written, taught and assessed curriculum (Ozdemir & Stebbins, 2015) and even the informal or "hidden" curriculum (Quirk, 2016; van den Heuvel et al., 2017). As noted by Piotrowski (2011), curriculum mapping and management systems must accommodate a variety of curricular models, particularly in medicine. For example, a curricular orientation may be outcomes-based and student-centred (Balzer, Hautz et al., 2016; Kies, 2010; Komenda, Schwarz, Vaitsis et al., 2015; Watson et al., 2007) or practice-based and patient-centred (Balzer, Bietenbeck et al., 2015; Sarkisian & Taylor, 2013; Wong & Roberts, 2007). Table 2 outlines the parameters and possible options evident for dimension two.

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Table 2

Dimension Two: Map Product (curricular components) What to map?				
Parameter	**Possible Options**			
Curriculum dimension captured	Planned (declared, written, intended)	Taught (delivered, enacted)	Assessed (tested)	Learned (lived, hidden, informal)
Type of educational program	Undergraduate/ graduate (degree)	Postgraduate (masters, internship)	General degree program (arts, science, social sciences, etc.)	Professional degree program (medicine, law, engineering, etc.)
Curriculum orientation (model, structure, strategy)	Discipline-based, problem-based, case-based, outcomes-based, practice-based, experience-based	Single discipline or subject, multidisciplinary, horizontally or vertically integrated, spiral	Single profession, interprofessional	Teacher-centred, learner-centred, workplace-centred, patient-centred, population-centred
Learning unit or period captured	Courses, blocks, modules (semesters, years, phases)	Learning activities, assessment activities	Topic area, discipline area, system area	Work placements (e.g., clinical, community, industry)
Educational setting of activity	Campus setting	Workplace setting (clinical, community, industry, etc.)	Online, virtual setting	
Curriculum elements mapped	Graduate outcomes (skills, competencies, professional standards) Learning objectives (subjects, topics, disciplines, key concepts)	Learning opportunities (courses, lectures, tutorials, etc.) Learning contexts (problems, cases, work-related placements) Learning materials (lecture notes, readings)	Assessments (methods, activities, descriptions, items, linked outcomes, timing, delivery, duration)	Resources (teachers, coordinators, students, teaching rooms, timetables)
Number of curriculum elements	Two to three datasets	Four to five datasets	Six to seven datasets	More than seven datasets

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Dimension three: Process (actions used to capture curricular data)

This dimension considers the various human processes used to map a curriculum, such as how and when mapping is introduced into an educational program, what data sources are used, who is involved in collecting, reviewing and validating data and how often data are revised. The literature suggests that the direct involvement of students or trainees in reviewing curriculum maps (Plaza et al., 2007; Wong & Roberts, 2007; Zelenitsky et al., 2014) and of teachers in providing, entering and revising curriculum data (Balzer, Hautz et al., 2016; Mazurat & Schonwetter, 2008; Taleff et al., 2009; Watson et al., 2007; Zelenitsky et al., 2014) promotes a sense of collaboration and pedagogical reflection (Fritze et al., 2018; MacNeil & Hand, 2014; Sarkisian & Taylor, 2013; Spreckelsen et al., 2013) that is sometimes lacking from audit-like mapping processes where curriculum administrators or evaluators collect, validate and analyse data on a teacher's behalf (Figueroa et al., 2015; Keijsers et al., 2015; Malone et al., 2015). Maps that form an integral part of a curriculum development and review process (Al-Eyd et al., 2018; Balzer, Hautz et al., 2016; Dassel et al., 2018; Fritze et al., 2018; Komenda, Schwarz, Vaitsis et al., 2015; Olmos & Corrin, 2011; Steketee, 2015; Talbot et al., 2007; Zelenitsky et al., 2014) and are updated at regular intervals or continuously in real-time are considered more pedagogically useful than one-off mapping exercises that mostly form part of an audit or monitoring process (Britten et al., 2014; Collins et al., 2017; Malone et al., 2015; Neiworth et al., 2014). Table 3 outlines the parameters and possible options evident for dimension three.

Dimension four: Display (the application used to store and display curriculum data)

Our findings suggest that the complexity of the platforms used to display data can range from a static table or matrix developed in a text file or spreadsheet that is used to map a small number of curriculum elements (Britten et al., 2014; Collins et al., 2017; Dintzner, Nemec, & Tanzer et al., 2016; Dintzner, Nemec, Tanzer, & Welch et al., 2015; Malone et al., 2015; Perlin, 2011; Zelenitsky et al., 2014) to an advanced web-enabled database used to map numerous curriculum elements (Britton et al., 2008; Denny, Smithers, Armstrong, & Spickard, 2005; Ellaway, Albright et al., 2014; Hege et al., 2010; Komenda, Schwarz, Vaitsis et al., 2015; Komenda, Víta et al., 2015; Lee et al., 2003; Newcastle University (UK), 2010; Spickard & Denny, c 2014–2018; Spreckelsen et al., 2013; Watson et al., 2007) and link to learning analytics (Ozdemir & Stebbins, 2015; Quirk, 2016), and with assessment (Dexter et al., 2012; Lee et al., 2003; Steketee, 2015). The data in these more advanced display tools are often tagged with metadata (Komenda, Schwarz, Švancara et al., 2015; Steketee, 2015; Stoddard & Brownfield, 2018; Willett et al., 2008) and can be searched (Dexter et al., 2012; McGrath et al., 2006; Spreckelsen et al., 2013; Watson et al., 2007), visually represented or graphed (Balzer, Hautz et al., 2016; Canning et al., 2017; Dexter et al., 2012; Fritze et al., 2018; Komenda, Víta et al., 2015) and analysed for reporting requirements (Dexter et al., 2012; Ellaway, Pusic et al., 2014; Fritze et al., 2018; Komenda, Víta et al., 2015; Olmos & Corrin, 2011; Ozdemir & Stebbins, 2015; Steketee, 2015). While online

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Table 3

Dimension Three: Map Process (actions) How to map?				
Parameter	**Possible Options**			
Implementation of mapping	Partial or incremental (used to map only some courses or a component of a program)	Whole-of-program (used to map most or all courses in a program)	Retrospective (introduced into an existing educational program)	Prospective (introduced as part of the development of a new educational program)
Data source	Course handbook or syllabus	Interviews or surveys of staff or students; focus groups	Actual learning activities, assessment activities	Work-based experiences (e.g., clinical practice, other fieldwork)
Data collection and review	Curriculum coordinator, developer, evaluator, researcher	Educational support staff, administrative staff	Teaching staff (lecturers, discipline or theme experts, trainers, tutors)	Students, trainees, graduates
Data validation	Course coordinators, curriculum managers	Individual teachers, colleagues	Curriculum teams, committees	Students, trainees, graduates
Data revision schedule	Non-continuous (a one-off or ad hoc data collection and mapping exercise)	Varied (depends on type of curriculum revision, governance processes)	At regular intervals (e.g., before start of a course, academic year)	Continuous (live, in real time)

database-driven systems can be powerful curriculum mapping and management tools, they are expensive to acquire and maintain, and often need substantial human and financial resources (Inzana, 2017). If adopting such systems, the literature advises to engage end-users throughout an iterative design and piloting process; conduct a needs-analysis; account for up-front and on-going costs; consider user access, data security and system interoperability issues; and provide user training and support (Canning et al., 2017; Fritze et al., 2018; Lee et al., 2003; Piotrowski, 2011; Watson et al., 2007). Table 4 outlines the parameters and options evident for dimension four.

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Table 4

Dimension Four: Map Display (information system) Which map tool?				
Parameter	**Possible Options**			
Data capture tool	Text document, spreadsheet	Database	Stand-alone or client-based system	Online system (web-enabled, cloud-based, mobile app)
Structure of collected data	Unstructured (documents, interviews)	Structured (in database tables or forms)	Static (single files, offline)	Dynamic (online, real time)
Data input method	Manual	Semi-automated	Fully automated	Use of semantic web, curricular technical syntax
Data tagging method	None used	Manual	Semi-automated	Fully automated
Data output	Lists, tables, hierarchical trees, matrices (plain text or hypertext)	Analytical graphs, charts, statistical data, reports, text files (PDF)	Data visualisation, auto-generated concept maps or mind maps	Curriculum modelling, data mining, learning analytics, algorithms
Query function	None or limited	Browsing (set views)	Searching (simple and advanced), use of synonyms	Customised reports, data exports
Data release	When approved	Immediate release	Time release	Cohort-restricted
Interoperability with other systems	None	Learning management systems	Other curriculum management databases	Other institutional databases
User access and data security	Not applicable	Levels of access (e.g., reader, editor), user authentication (single sign-on)	Access through firewalls (e.g., in hospitals), from rural and remote areas	Data revision (track changes), backups, server security
Information system design and development	Needs assessment, market scoping, prototype, user testing	Involvement of end-users, technical staff, other stakeholders	Custom-built, commercial, open-source, blended solutions	Developed in-house and/or externally (contractor)
Information system release and maintenance	In-house and/or external system maintenance	Tests, fixes, improvements, version releases	End-user support, help desk, help sites	Customisation of features and functions
Costing and resourcing	Upfront costs, ongoing costs	In-house costs, external costs	IT resources (staff, licences, hosting, servers, etc.)	Training and support of staff and students

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Discussion

Our literature review revealed many ways in which educators and curriculum developers have used curriculum maps to organise their curriculum. For example, maps have been used in a variety of higher education programs (e.g., undergraduate/graduate, postgraduate, professional, non-professional and trainee programs) and with different curriculum models, structures and strategies (e.g., discipline-based, problem-based, outcomes-based, integrated, student-centred, multidisciplinary) (Fraser & Thomas, 2013; J. Jacobs et al., 2005; Langlois, 2016; McGrath et al., 2006; Piotrowski, 2011; Taleff et al., 2009). This is noteworthy since some higher education programs present unique mapping problems due to their complex curriculum structures, such as diverse Bachelor of Arts programs (Fraser & Thomas, 2013). Maps have also been used with a select number of courses in a program, e.g., first year courses (Spencer et al., 2012), a whole program, e.g., undergraduate medicine (Al-Eyd et al., 2018; Balzer, Hautz et al., 2016; Fritze et al., 2018; Komenda, Schwarz, Vaitsis et al., 2015; Steketee, 2015), one component of a program, e.g., information literacy (Archambault & Masunaga, 2015; Buchanan et al., 2015), informatics (Collins et al., 2017) or components of programs across one or more institutions, e.g., generic skills, learning outcomes and professional competencies (Gluga, Kay, & Lever, 2013; Gluga, Kay, Lister, & Lever, 2012; Lawson, Taylor, French et al., 2015; Lawson, Taylor, Herbert et al., 2013; Oliver, 2013). In higher education, maps are often used for the constructive alignment of graduate outcomes, activities and assessments (Balzer, Hautz et al., 2016; Fritze et al., 2018; Kertesz, 2015; Oliver, 2013; Steketee, 2015) and to help detect gaps and redundancies in the curriculum (Buchanan et al., 2015; Joyner, 2016; Romkey & Bradbury, 2007; Steketee, 2015). Increasingly, maps are being used to audit learning outcomes, graduate competencies and professional standards for accreditation (Britten et al., 2014; Figueroa et al., 2015; Fritze et al., 2018; Malone et al., 2015; Neiworth et al., 2014; Perlin, 2011; Talbot et al., 2007). Al-Eyd et al. (2018) contend that how a curriculum is communicated is critical, but communicability and transparency are often overlooked at the expense of other curriculum elements, such as content, pedagogy and assessment.

The tension between maps used primarily for accreditation and maps used primarily for teaching and learning has been discussed by a number of authors (Kertesz, 2015; Knewstubb & Ruth, 2015; Lawson et al., 2015; Sumsion & Goodfellow, 2004; Tariq et al., 2004; Wang, 2015). Lawson, Taylor, French et al. (2015) warn that a curriculum-mapping process can be undermined by a "tick and flick" approach to mapping skills and competencies for accreditation. Tariq et al. (2004) observe that maps perceived by academics to be part of a quality assurance agenda can become "little more than a device to facilitate managerial auditing of teaching and learning at the expense of enhancing pedagogical processes" (p. 79). They note how crucial it is for staff to "understand that the mapping exercise is not the end of a process, but rather the start of reflection, which will enable them to use learning outcomes constructively to enhance their curriculum and modify practice" (p. 79). Kertesz (2015) suggests that while course renewal curriculum mapping might lend itself to accreditation, in an increasingly regulated education environment, it is worth exploring if accreditation mapping generates

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ongoing curriculum improvement. He emphasises the importance of continuing collegial input in the development of a curriculum map "to ensure that it remains a teacher-owned manageable tool for educational improvement that concurrently and in an unthreatening manner satisfies organizational compliance and wider accreditation requirements" (p. 25). This notion is supported by Quirk (2016), who in the discussion section of his webinar, highlights that while a medical school may introduce mapping through an administration or accreditation mandate or through a teaching mandate, what is important is to weave the map into the fabric of the school system and to involve faculty in the mapping process. Quirk broadens the interpretation of a curriculum map to a "curriculum positioning system" that offers a dynamic and interactive educational tool that enables faculty and students to establish competencies, learning strategies and milestones, and through which students can create personalised learning routes and an archive to reflect on their journey (Quirk & Chumley, 2018; Quirk & Harden, 2017). Wang (2015) goes on to see the learner as the cartographer and extends the aim of curriculum mapping from professional learning to lifelong learning. All this said, the choice of curriculum mapping tool—be it simple or advanced—will depend on the program budget and the availability of information technology support. Inzana (2017) provides a comprehensive list of open-source and commercial curriculum mapping software utilised in medical education.

The typology of curriculum maps discussed in this paper has emerged from our desire to better understand our own maps in medical education and apply lessons from the literature. In testing and validating this typology against our own curriculum maps, we were able to profile and describe the existing and aspirational parameters of our applications, depending on where we were in the development process (we intend to address these results in a separate article). The detailed parameters and options (tabulated within each dimension) allow the strengths and weaknesses of a map's features to be described, evaluated and, potentially, improved. The typology is also useful for identifying misalignments between the intended purposes of a map and the processes and products being used for the mapping exercise.

In this regard, the map typology can be used as a rubric for supporting decision making for the development of new maps or the improvement of existing ones. The choices made by curriculum mappers will have practical implications for program delivery, evaluation and educational research. For example, more granular maps will be more useful for students and teachers to review and integrate components of the curriculum, and for educational staff as an assessment blueprint for item development. Less granular maps will be useful for overall course design and structure. Maps can be developed to assist in the design and data collection for educational research studies to further the evidence base in health professions education. Our typology may, therefore, assist curriculum owners and end-users to prioritise parameters and options (e.g., prioritisation of terms and requirements, human resources, budgetary constraints). Options selected would depend on many factors, so that what is optimal or desirable in one situation may not be so in another. The typology may also be a useful tool to engage curriculum stakeholders, decision makers, evaluators and researchers in the curriculum-mapping process.

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Conclusion

We derived from the literature an inclusive typology for describing a wide range of curriculum maps used in higher education, relevant to the health professions. The literature was analysed to better understand the diversity of examples evident within four key dimensions that are fundamental to curriculum maps (i.e., What is the purpose? What data or curriculum components does the product map? What processes are used to map the data? How is the data captured and displayed?). Each of the four dimensions was subsequently expanded into a set of parameters with descriptors for each to describe the array of possibilities evident within the literature. Each of the dimensions and parameters was revised and refined using a validation process tested against curriculum maps at different stages of development, from six diverse medical programs. The potential of the typology as a lens through which the affordance of maps can be analysed was strengthened through this process.

In providing a structured framework and common language with which to describe and compare curriculum maps, we believe our study adds to the field of knowledge on curriculum map development, use and research. Further work to extend the application of our typology to planning, implementing and researching curriculum mapping is needed to test the robustness of our findings.

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