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O2

Methodological and technical step-by-step manual on curriculum innovations in medical and healthcare study fields

by BCIME team

Intellectual Output Description

Output Identification	O2
Output Title	Methodological and technical step-by-step manual on curriculum innovations in medical and healthcare study fields
Output Description (including: elements of innovation, expected impact and transferability potential)	This output covers the compilation of recommendations and best practices to improve a platform for medical and healthcare curriculum management as well as optimise curriculum innovations and mapping processes. The activity will depend on outputs of O1 activity that will be used in combination with expertises of partner institutions to compile optimal methodological material acceptable not only for curricula in medical education.
Output Type	Methodologies / guidelines – Methodological framework for implementation
Please describe the division of work, the tasks leading to the production of the intellectual output and the applied methodology	There are following tasks and roles of each partner's institution: *** UPJS - Guidelines methodological co-authoring and proofreading. *** JU - Guidelines preparation in terms of methodological, pedagogical and technical perspective. Design and implementation of domain for online publishing of achieved results (guidelines, state-of-the-art, etc.). *** UMF - Guidelines pedagogical co-authoring. Guidelines internal review. *** UAU - Guidelines methodological and pedagogical co-authoring. Internal review. *** MU - Good practice receiver. Guidelines technical co-authoring. Establishment of the communication node for involved stakeholders (MEFANET, MedBiquitous).
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1. Aims

In agreement with the BCIME project bid, we have structured this intellectual output (IO) report to "cover the compilation of recommendations and best practices to improve a platform for medical and healthcare curriculum management, as well as optimise curriculum innovations and mapping processes." Our activities aimed to use outputs of IO1 that combined with expertise of partner institutions would result in high quality methodological material tailored for the needs of medical education, but potentially generalisable for curricula in other disciplines.

2. Introduction

As result of the specific needs analysis conducted at project partners' faculties (IO1) completed in the time between September and December 2018, a set of 12 key characteristics was postulated to be implemented in the curriculum management platform [1].

The established key characteristics are listed below:

1. Available online
2. Visual overview of curriculum
3. Integration of different user roles
4. Export of curricula by course, study field, department, faculty
5. Visual relations between various components of curriculum
6. Possibilities to search by keywords
7. Integration of international recommendations
8. Possibility to modify reports and outputs according to the institutional requirements
9. Evaluation of learning objectives
10. Identification of redundancies in learning objectives
11. Outcome-based education compatibility
12. Complex reporting based on available curriculum building blocks

Those twelve key characteristics were selected as a coding frame to structure the compilation of recommendations and best practices to improve the platform for medical and healthcare curriculum management. In addition, we roundup these points by presenting (13.) step-by-step recommendations for a process how to implement the changes and (14.) a reflection on generalisability of the results to other disciplines.

3. Methods

There are two main sources of recommendations given in this report. On the one hand we take advantage of experiences collected by project partners in managing their curricula so far. On the other hand, we extend it by presenting lessons learned on designing curriculum mapping software reported in literature and published during the last five years.

3.1 Partners' local good practice and needs

Project partners were asked to consider what from their previous experience, international standards or national regulations could be interesting and inform the development of the curriculum mapping system. Included is former, successful practice which led to obtaining a functional curriculum (even if it was only paper-based or semi-automatic), national regulations (like national learning objectives frameworks and catalogues), international catalogues of learning objectives for project relevant disciplines and software solutions which are used locally, but could inform building a more universal software solution by the BCIME project.

3.2 Literature review on good practice in curriculum management software design

As many of the project partners are newcomers in electronic curriculum management and curriculum mapping, we also searched the most recent literature for published best practice and lessons learned.

Inclusion criteria were:

- Descriptive studies presenting
    - computerised tools or web-based platforms for curriculum mapping
    - algorithms, visualisation methods, frameworks and models of computer-aided curriculum mapping
- Studies reporting on curriculum design, analysis or mapping when description of a dedicated software tool for that purpose is emphasized in the abstract
- Systematic reviews on curriculum design methods when covering software tools for curriculum mapping and innovation

Exclusion criteria were:

- Studies describing
    - curriculum design or structure when software support is not mentioned in the abstract
    - models for curriculum design
    - development of individual courses or learning resources
    - development of on-line curricula (curricula of programmes that are taught on-line)
    - results of (inter-)national surveys (questionnaires) about implementation of specific learning objectives in curricula
    - students' perspectives on curricula
    - curriculum design in pre-university education
    - communication software in use for collaborative development of curricula (e.g. Tumblr)
- Needs assessment for a curriculum reform
- Systematic reviews comparing differences in curricula when the comparison was manual and did not include dedicated curriculum mapping software (e.g. ultrasound in medical curricula)
- Evaluation of programmes, courses or e-learning resources
- Conference abstracts, letters to editor, comments

Based on literature collected on the topic prior to review and our own experiences, a list of search terms was proposed. We classified them in methodological/pedagogical and technical keywords (Tab. 1).

Tab. 1 Methodological/pedagogical and technical keywords in use in the literature search

Methodological/pedagogical keywords	Technical keywords
• Curriculum map* • Curriculum development • Curriculum management • Medical curricula • Healthcare curriculum • Curriculum reform • Curricular innovation* • Curriculum innovation*	• Software • Management system* • Database* • Web-based • Computer* • Online • On-line • Mapping Tool* • Digital • Electronic • Information system* • Visual analytic* • Academic analytic* • Data mining • Text mining • Platform

In order to be included in the review, an abstract had to contain both a methodological/ pedagogical keyword and a technical keyword. In addition, we have hand-searched reference lists of all here included studies.

To keep the workload in the time constraints given for the intellectual output, we decided to limit the scope of literature review to the last 5 years: **January 1st, 2013 - now**. Standards for systematic reviews usually recommend to query several literature databases. Considering the limited time resources allocated to this task in the project budget, we focused the literature query on the PubMed/ Medline reference database, acknowledging this as a limitation of this study.

The detailed query in PubMed/Medline syntax is presented in Tab. 2.

Tab. 2 PubMed/Medline query on curriculum mapping software innovation

```
((Curriculum map*[Title/Abstract] OR Curriculum development[Title/Abstract] OR Curriculum
management[Title/Abstract] OR Medical curricula[Title/Abstract] OR Healthcare
curriculum[Title/Abstract] OR Curriculum reform[Title/Abstract] OR Curricular
innovation*[Title/Abstract] OR Curriculum innovation*[Title/Abstract])

AND

(Software[Title/Abstract] OR Management system*[Title/Abstract] OR Database*[Title/Abstract] OR
Web-based[Title/Abstract] OR Computer*[Title/Abstract] OR Online[Title/Abstract] OR On-
line[Title/Abstract] OR Mapping Tool*[Title/Abstract] OR Digital[Title/Abstract] OR Electronic
[Title/Abstract] OR Information system*[Title/Abstract] OR Visual analytic*[Title/Abstract] OR
Academic Analytic*[Title/Abstract] OR Data mining[Title/Abstract] OR Text
Mining[Title/Abstract] OR Platform[Title/Abstract]))

AND

("2013"[Date - Publication] : "3000"[Date - Publication])
```

The query was last updated on **March 10th, 2019**. A PRISMA study flow diagram is presented in Fig. 1.

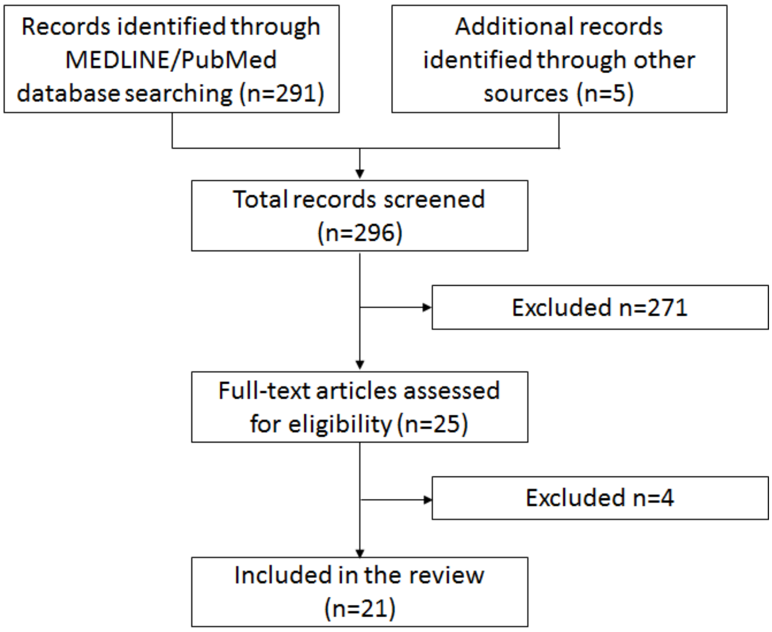

Fig. 1 PRISMA study flow diagram of the literature search

The search resulted in 291 abstracts. Those were uploaded to the Mendeley reference management software, screened, and if met inclusion criteria retrieved and analysed by the project consortium. As a result of the screening process we downloaded full-text versions of 25 studies. On detailed inspection we subsequently excluded four studies that covered topics not directly relevant to the aims of our query (e.g. dealing with repositories of reusable learning objects or focusing on review of curricula of particular medical disciplines). Through a manual search of references, we could include five more studies. The final list of reviewed paper included 21 studies. Finally, we analysed the obtained collection of studies in detail and searched them for guidance that could inform the development of the above mentioned twelve specific key characteristics and two special themes.

4. Results

4.1 Available online

As result of our literature query, we were able to locate the following electronic curriculum management and mapping systems reported to be in use in the last 5 years (presented in alphabetical order in Tab. 3).

Tab. 3 Electronic curriculum management and mapping systems in use in the last 5 years

Name	Description	Ref
ACLO-Web	A system for collaborative authoring and managing of learning objectives developed at the RWTH Aachen (Germany) using Semantic Web technologies. The system is based on a MediaWiki platform and enables	[2]

	adding learning objectives for all courses in the curriculum. ACLO CM is a module dealing with consistency checking of the curriculum.	
CLUE (LKCMedicine Curriculum Explorer)	A custom-built curriculum mapping system developed at LKC School of Medicine in Singapore. Based on information pooled into a data warehouse from several sources.	[3]
Electronic Thematic Map (of the University of Iowa College of Dentistry)	A locally developed system to address the curriculum mapping needs of University of Iowa College of Dentistry. No information available whether the system has been used in other setting or is still available.	[4]
LOOOP	"Learning Opportunities, Objectives and Outcome Platform" (LOOOP). A system developed over nine years by Charité – Universitätsmedizin Berlin hospital [5]. Currently in use by several German medical faculties and used as tool to further develop the NKLM. https://looop.charite.de/en/	[5]
medtrics	Proprietary product implemented by a commercial company. Reported to be in use at California University of Science & Medicine [6]. https://www.medtricslab.com	[6]
MER*LIN*	A joint project of several German universities led by University of Tübingen. Six faculties completed mapping of the whole curriculum using this tool. In total 14 are using it. Implemented several visual analytics presentations. Closely integrated with the German national competency catalogue (NKLM). http://www.merlin-bw.de	[7–9]
OPTIMED (OPTImized MEDical education)	A modular curriculum mapping system developed at Masaryk University, Brno, Czechia. Consists of four components: a) a learning outcome register; b) learning unit register; c) curriculum browser; d) reporting and export module. http://opti.med.muni.cz/en	[10–14]
Prudentia	A curriculum mapping system developed at the University of Notre Dame, Australia. https://www.notredame.edu.au/staff/work/LTO/prudentia	[15]

Other systems mentioned by name in the reviewed papers, but not described in details were: CMaps [16], eMed [17], Entrada [18,19], E*Value [18], Illios [15], One45 [18], Rubicon Atlas [15], SOLE [18].

All of the described systems were implemented using web technologies and designed to be operated via plain web browsers. It is not surprising as web graphical user interfaces are readily accepted by users. For instance the authors of the LOOOP system reported their product is in use by more than 95% of students at their institution, a number which is even better than was anticipated by the developers [5].

The curriculum mapping systems were implemented using different specific technologies, seldom named explicitly in the reports. Fritze et al. [7] implemented their MER*LIN* platform in PHP/MariaDB technology. As a software library for visual analytics graphs they applied jpGraph. Komenda et al. developed the OPTIMED system using PHP/PostgreSQL [13]. Graphical plots were presented using D3.js and NVD3 libraries [10]. Spreckelsen et al. developed their system based on the MediaWiki platform and Semantic Web technologies (RDF, OWL, SPARQL) [2].

Aldrich [20] collected curriculum data from the university website using Python language scripts and represented it then as a curriculum prerequisite network using the NetworkX library. Vaitsis et al. [21] presented visualisations of the curriculum for analytic purposes using the Cytoscape software. Those presentations were created *ad hoc* as prototypes and were not part of a dedicated curriculum mapping software system in regular use by administration, teachers or students. Komenda et al. [12] applied yEd Graph Editor to represent coverage and associations between descriptors from the MeSH tesaurus and the curriculum map of Masaryk University. This research team applied also the statistical package R for more in depth analyses of the curriculum map including Social Network Analysis and similarities detection based on text-mining [11,14].

Despite all the advantages of web presentation, some of the system still retain an option for a traditional print-out. For instance in the MER*LIN* system a PDF export of the content for “take-away” (e.g. schedules) is still used by many students and considered important part of the user interface [7].

The analysed literature confirmed our intention to design the system to be available on-line and delivered several visual examples on how to design web user interface.

4.2 Visual overview of curriculum

The natural evolution of electronic curriculum mapping systems often starts with the idea of presenting the curriculum in a tabular form in popular office tools like Microsoft Excel, Word or Access. Although static text documents or spreadsheets are often later replaced by more complex presentation forms, the first generation of curriculum map gives a satisfactory overview of the curriculum, highlight the priorities in visualisation and therefore is worth attention.

A good example of that is the curriculum map in use at the British Columbia University, Alberta, Canada [19]. Jarvis-Selinger & Hubinette present in their study a curriculum renewal process implemented using a Microsoft Excel spreadsheet dubbed “The Matrix” with hyperlinked Microsoft Word documents called “virtual course books” providing more details about individual weeks in the curriculum.

The Matrix spreadsheet presents in columns: Systems (major biomedical systems, e.g. cardiovascular, digestive, urinary); Themes (e.g. medical sciences (e.g. Anatomy and Embryology), Treatment (e.g. Counselling), Care of Patients (e.g. eHealth and Informatics)) and Clinical Experiences. Rows of the Matrix form weeks of the program/specific topics or patient presentation (e.g. hypertension, breast mass). The cells present week-level objectives (focus of teaching of the week) detailed in virtual course book.

A similar method is applied for medicine program at Jagiellonian University Medical College, where a matrix was conceived as a result of the need to map the new national learning outcomes catalogue into traditional discipline-based curriculum. It presents:

- in rows - all learning outcomes to be achieved by medical graduates,
- in columns - all subjects taught in medicine program,
- in cells - departments/clinics assigned to teach specific learning outcomes during specific subjects.

The main function of this tabular presentation is an allocation of every learning outcome to specific department(s) and specific subject(s) (Fig. 2).

	Obszary tematyczne			C. NAUKI PRZEDKLINICZNE		
	Przedmiot		Telemedycyna z elementami symulacji medycznej	Genetyka z biologią molekularną	Genetyka kliniczna	Mikrobiologia z parazytologią i immunologia
	Rok studiów		2	1	4	2
	liczba efektów		27	16	16	19
B.U23.	umie korzystać ze sprzętu do odtwarz...	1	Zakład Bioinformatyki i Telemedycyny			
B.U24.	umie korzystać z internetowych baz ge...	1	Zakład Bioinformatyki i Telemedycyny			
B.U25.	umie korzystać z internetowych baz d...	1	Zakład Bioinformatyki i Telemedycyny			
B.U26.	umie posługiwać się narzędziem telem...	1	Zakład Bioinformatyki i Telemedycyny			
B.U27.	umie korzystać z różnego typu symula...	1	Zakład Bioinformatyki i Telemedycyny			
B.U28.	umie korzystać z symulatorów komput...	1	Zakład Bioinformatyki i Telemedycyny			
B.U29.	umie przedstawić wiedzę ekspercką z...	1	Zakład Bioinformatyki i Telemedycyny			
B.U30.	umie zabezpieczyć dane kliniczne prze...	1	Zakład Bioinformatyki i Telemedycyny			
B.U31.	umie korzystać z platform e-nauczania...	1	Zakład Bioinformatyki i Telemedycyny			
B.U32.	umie przygotować materiały do prezen...	1	Zakład Bioinformatyki i Telemedycyny			
C.W1.	zna podstawowe pojęcia z zakresu gen...	2		Zakład Biol. Molekul i Genetyki Klin.	Zakład Genetyki Medycznej Katedry Pediatrii	
C.W2.	opisuje zjawiska sprzężenia i współdzi...	1		Zakład Biol. Molekul i Genetyki Klin.		
C.W3.	opisuje prawidłowy kariotyp człowieka...	2		Zakład Biol. Molekul i Genetyki Klin.	Zakład Genetyki Medycznej Katedry Pediatrii	
C.W4.	opisuje budowę chromosomów oraz m...	1		Zakład Biol. Molekul i Genetyki Klin.		
C.W5.	zna zasady dziedziczenia różnej liczby ...	2		Zakład Biol. Molekul i Genetyki Klin.	Zakład Genetyki Medycznej Katedry Pediatrii	
C.W6.	zna uwarunkowania genetyczne grup ...	1		Zakład Biol. Molekul i Genetyki Klin.		
C.W7.	opisuje aberracje autosomów i hetero...	2		Zakład Biol. Molekul i Genetyki Klin.	Zakład Genetyki Medycznej Katedry Pediatrii	
C.W8.	zna czynniki wpływające na pierwotną...	2		Zakład Biol. Molekul i Genetyki Klin.	Zakład Genetyki Medycznej Katedry Pediatrii	
C.W9.	zna podstawy diagnostyki mutacji gen...	3		Zakład Biol. Molekul i Genetyki Klin.	Zakład Genetyki Medycznej Katedry Pediatrii	
C.W10.	określa korzyści i zagrożenia wynikają...	1		Zakład Biol. Molekul i Genetyki Klin.		
C.W11.	zna genetyczne mechanizmy nabywan...	2		Zakład Biol. Molekul i Genetyki Klin.		Katedra Mikrobiologii
C.W12.	klasyfikuje drobnoustroje, z uwzględni...	1				Katedra Mikrobiologii
C.W13.	zna epidemiologię zarażeń wirusami, ...	1				Katedra Mikrobiologii
C.W14.	zna wpływ abiotycznych i biotycznych ...	3				Katedra Mikrobiologii
C.W15.	zna inwazyjne dla człowieka formy lub...	1				Katedra Mikrobiologii
C.W16.	omawia zasadę funkcjonowania układ...	1				Katedra Mikrobiologii
C.W17.	zna objawy zakażeń jatrogennych, dro...	1				Katedra Mikrobiologii

Fig. 2 An excerpt from a matrix used to map curriculum at Jagiellonian University Medical College

However, as the expectations of the curriculum map functionality grow, the use of generic spreadsheet programs leads to technological constraints related to the limited amount of information that a spreadsheet may contain. The authors of the Matrix at British Columbia University stated in the conclusions of their paper they were, since 2015, in the stage of translating the Matrix to a curriculum mapping system called Entrada, developed by Queen's University, Kingston, Ontario, Canada [19]. Similarly, Steketee reported on early attempts at curriculum mapping to use for that purpose Microsoft Access, but it was discovered quickly that "more 'logic' needed to be imposed onto the curriculum for this or any other application to work effectively", as effect of which the Prudentia web-based system was developed [15]. The impulse to develop the MER*LIN* electronic curriculum mapping system at the University of Tübingen was the refusal of some departments to use for the mapping task an extensive Excel spreadsheets [9].

Graphs and networks offer a more user friendly alternative to the tabular representation of the curriculum. The difference between those two alternatives is that the networks are specialised graphs that may contain attributes of nodes and edges. For instance, Aldrich [20] represents the curriculum at the Benedictine University as a complex directed acyclic graph. In the analysis of the curriculum following concepts from graph theory, the following elements are used: node degree, shortest path, betweenness centrality and connected components. This allows isolated components of the curriculum, hub components and learning communities to be identified. For a visually compact and legible curriculum graph, Aldrich applied the Kamada-Kawai force-directed method [20]. Komenda et al. [12] showed by a complex graph (association map) how medical topics represented by MeSH descriptors are associated in learning units in the curriculum map of Masaryk University. In another study the same team of researchers used similarity graphs to show clusters (communities) of closely related disciplines in the curriculum [14]. The degree of similarity was calculated using measures of centrality (closeness, betweenness and eigenvector centrality).

Networks and graphs represent a sophisticated way of visualising the curriculum, but for complex datasets may grow in size to a form that is difficult to understand. More condensed forms of visualisation may come in handy. For instance, in a solution for displaying the curriculum map proposed by Hege & Fischer, the graph is converted into a tree model [22].

Fritze et al. provide a comprehensive overview of divers visualisations that is used in the curriculum mapping system MER*LIN* [7]. Those include bar, pie doughnut and balloon charts as well as color-coded tables. For instance, the longitudinal profile of implementing specific learning objectives in the whole curriculum is presented in form of bar charts. The bars show frequency of presence of specific learning objective across semesters. Yellow bars are objectives implicitly taught, blue - the objectives explicitly taught at different levels of competency.

Another form of controlling complexity for a more comprehensible overview of the curriculum is based on combinable filters, for example by selecting the descriptors (diagnoses, symptoms), departments, or objectives from national catalogues as available in the LOOOP system [5]. The four overviews of the curriculum available in the ACLO-Web system are: a list ordered by the curricular module, medical speciality responsible for learning objectives, medical topic, and MeSH-based learning objective category [2].

Using such visualisations, the curriculum becomes transparent, teachers and students can see their position in the field and their expected involvement in the entire curriculum. This may also help in interdisciplinary communication [23].

4.3 Integration of different user roles

As it was underscored by Harden [24], an important step in developing a curriculum map is "allocating responsibilities for the map". The analysed literature reports different user roles defined and proved to be useful in managing the curriculum mapping process using software tools.

Fritze et al. [7] differentiates three roles in administration of the software tool:

- A **global administrator**: responsible for configuration and adaptation of overarching structures (e.g. program organisation, learning objectives catalogues update, mapping options).
- A **local administrator**: responsible for on-site management of the organisational structures. This involves e.g. entering the site-specific terminology and definition of local characteristics. That person is also responsible for local user management.
- The group of **local users**: responsible directly for the entry and review of curriculum mapping data. Involves both mappers and curriculum developers.

Balzer et al. developed "a hierarchical system of online users roles with specific responsibilities" to structure "respective rights to read or write in the designated sections of LOOOP" [5]. For instance, allocated patient numbers, ward teaching capacity and teacher assignments are available for teachers and curriculum planners only. Users have the right to edit subordinated processes. All their changes are tracked and can be visualised.

In the paper by Cottrell et al. [18], two user role models of curriculum mapping are presented. A **decentralised** model with individual course and clerkship directors annotating individually their courses with tags from a controlled vocabulary (University West Virginia); and **centralised** model with 1-2 points of contact to collect session plan templates to be entered into the curriculum mapping system (Texas A&M). Both models are feasible and have their strengths and weaknesses.

Komenda et al. used in their OPTIMED system a third party authentication and authorisation service provided by eduID.cz (Czech Academic Identity Federation) which allows login to the system of academic staff and students from universities across Czechia [13]. This solution has the strength that no separate usernames and passwords need to be remembered to securely access the curriculum mapping system. Moreover, various system roles like student, teacher, curriculum designer, guarantor and head of department have been defined and systematically used during a process of curriculum description and optimisation.

A very open approach to curriculum mapping authoring is presented by Spreckelsen et al. [2] which enables all faculty members to edit all learning objectives. Safety of this solution is warranted by the possibility to undo changes from wiki page history. However, this policy is regarded by many users as controversial and part of the faculty demands an introduction of more fine-grained roles.

In summary, it is recommendable to introduce a hierarchy of users including such roles as student, teacher, curriculum planner and administrator. Each of those roles has its unique perspective and requirements. Access for students, for instance, should be quite open and versatile, whereas the functions of curriculum planners more complex and better protected. If possible, a federated single-sign on mechanism for the users is welcomed. A mechanism for tracking changes helps in assuring system safety and transparency.

4.4 Export of curricula by course, study field, department, faculty

A curriculum mapping software tool should not be an isolated data island, but has to interact with other elements of the university information infrastructure. There is a need of reporting and data exports for external entities like accreditation or benchmarking purposes. A support for custom interfaces and data interoperability standards is a valuable feature.

The most frequently mentioned data exchange standard is the American National Standards Institute **Curriculum Inventory** developed by a collaboration of Association of American Medical Colleges (AAMC), the MedBiquitous Consortium and other stakeholders [25]. This technical specification is based on an object-oriented model that defines many different curriculum structures at different levels of complexity using a few building blocks or elements. The elements defined by the standard are:

- Base components
  - **Events** - when things happen (e.g. lectures, PBL session, virtual patient session)
  - **Expectations** - what things were intended to achieve; the intended end state: objectives, competencies, or learning outcomes
- Curriculum organisation and structure
  - **Academic level** (e.g. year, phase)
  - **Sequence block** - aggregation of events; can be nested; may be preconditioned; or have post-conditions; may reference associate expectations and academic level in which they occur

- **Integration blocks** - "groups items (such as Expectations and/or Sequence Blocks) to show how topics or expectations are addressed longitudinally or recurrently throughout the curriculum" (e.g. high-level themes, threads or spirals); lenses to see how topics are addressed in the curriculum

- Common vocabulary - i.e. standardized terms to be used to describe particular activities

The MedBiquitous Curriculum Inventory standard sets technical syntax through which a wide range of different curricula can be expressed and subsequently compared and analysed [25]. For instance, AAMC gather medical school curriculum data from curriculum management systems using this standard to a central repository that enables in depth analyses and reports. The MedBiquitous Curriculum Inventory is supported by ancillary specifications: MedBiquitous **Competency Object** (description of each expectation) and MedBiquitous **Competency Framework** (how expectations relate to one another both hierarchically and non-hierarchically).

It is challenging to keep a clear borderline between various types of systems which functionality intersects and might lead to information redundancy and inconsistencies. Willett distinguished four types of curriculum mapping systems differing in focus of functionality [26]. These types are curriculum mapping systems dealing mainly with aspects of a) scheduling; b) assessment; c) learning outcomes analysis and d) ontology based information retrieval. To that adds lack of clarity about the use of popular electronic infrastructure systems like learning management systems, e-portfolios, campus management systems or exam software. From the user's perspective it might be difficult to comprehend the distinctions between the specialised tools.

Steketee recommends it is important to clarify confusion about overlaps between what a curriculum mapping system is aiming to do and what a learning management system is already providing [15]. In their study they discuss the need for an interface combining the functionality of their curriculum mapping system Prudentia with Blackboard Learning Management System.

Such interfaces help in implementing curriculum mapping in blended learning curricula which is postulated at an increasing number of higher education institutions. For example, at the medical school of the University Augsburg, longitudinal courses about clinical and scientific competency are planned as inverted classroom formats. Also, other modules will include up to 30% online courses in a blended learning setting. Learning objectives for blended learning courses (online and face-to-face) are collected in a curriculum mapping software tool and made available to the students. However, learning objectives for the online phases are also gathered and displayed to the students within the e-learning tools and systems, such as Moodle learning management system and CASUS virtual patient system and made available directly in the courses as resources [22]. A major disadvantage of such a duplicate data storage is that updates have to be made at two places and risk of discrepancies are high. Therefore, a modern curriculum mapping software system should provide standard interfaces to receive learning objectives from learning management and e-learning tools.

Requirements for such interfaces include an agreed description/specification (xml schema) of learning objectives between curriculum mapping software and e-learning tools, triggered by push from e-learning systems (when changes have been made) and a SOAP or REST based technical interface. For the realisation of such an interface, an exploration of the MedBiquitous competency framework could also be helpful.

At Jagiellonian University a likely source of confusion and maybe even resistance to use a new curriculum mapping tool is the potential overlap of this system with another one called USOS that provides timetables, student lists, feedback, gradebooks and unstructured syllabi. This would correspond to a clash between the first and third classes of curriculum mapping tools in the typology described above by Willett [26]. Guidance for how to avoid data redundancies, inconsistencies and confusion among the users on which system to use for which purpose is needed.

Further examples of information exchange between curriculum mapping software and other IT systems found in the literature are the interfaces to electronic scheduling systems. In the LOOP system, study guides and plans for daily usage can be exported in iCal format [5]. Spreckelsen et al. [2] developed interfaces of their curriculum mapping system to a semantic network used to index learning media and to an online calendar and room management system. The curriculum mapping solution developed at Ludwig-Maximilians-University in Munich allows the export of the curriculum graph in GML syntax which is compatible with many graphical representation and analysis tools [22].

Canning et al built their curriculum mapping system CLUE using a data warehouse solution. Data is pooled together from three sources: a learning objects database, learning resources repository and timetable of associated learning activities [3].

Finally, Komenda et al investigated algorithms for similarity detection between virtual patient cases in the Akutne.cz portal and the curriculum map in the OPTIMED system [11]. This opens the possibility for using curriculum mapping systems in automatic discovery of learning resources for adaptive learning.

4.5 Visual relations between various components of curriculum

Relations between elements of a curriculum may be of diverse nature. Based on the literature review we were able to distinguish several of them including: prerequisites, broader/narrower relationship, thematic association and constructive alignment.

Prerequisites show a relation of thematic dependency. Students willing to attend a given course need first to complete a range of more basic learning activities or attain a list of learning objectives. This relation is visualised by networks in the study by Aldricht [20] or trees in the study by Hege & Fischer [22].

The broader/narrower relationship is often used in curriculum mapping software to show how general learning outcomes or objectives (e.g. at the national accreditation catalogue level) are decomposed into more fine grained objectives, down to the level of individual learning sessions or even test items in summative examinations.

For instance Jarvis-Selinger [19] introduces a hierarchy of learning objectives at five levels: Global exit competencies; Year level milestones; Course outcomes; Week-level objectives; Individual session objectives. In the Matrix, view the week-level objectives are visually mapped to year-level milestones and deconstructed into individual sessions objectives in virtual course books.

In Prudentia, a five level curriculum framework is implemented [15]: Level 1: AMC attributes (national accreditation catalogue) and Notre Dame Graduate Attributes (local university learning objectives catalogue); Level 2: MBBS Course Outcomes; Level 3: Unit Goals; Level 4: Broad Learning

Outcomes; Level 5: Specific Learning Outcomes (learning encounters in individual sessions). Prudentia links micro level specific learning objectives (Level 5) back up to the level of course outcomes and accreditation standards. Representation of this relationship may be later on used in analyses to determine the extent to which the curriculum actually reflects the required domains representation (e.g. required percentage of basic clinical sciences; communication and clinical practice; or personal and professional development).

In the *medtrics* system presented by Al-Eyd et al. the learning outcomes are described at four levels: ILOs - Institutional Learning Outcomes; PLOs - Program Learning Outcomes; CLOs - Course Learning Outcomes and SLOs - Session Learning Outcomes [6]. The systems support curriculum analysis by showing the relationship across different levels of learning outcomes and their associated learning events, pedagogy, and assessment. This is visualised by listings curriculum components in two columns showing higher level learning outcomes (boxes) grouped below the respective lower level (Fig. 3) [6].

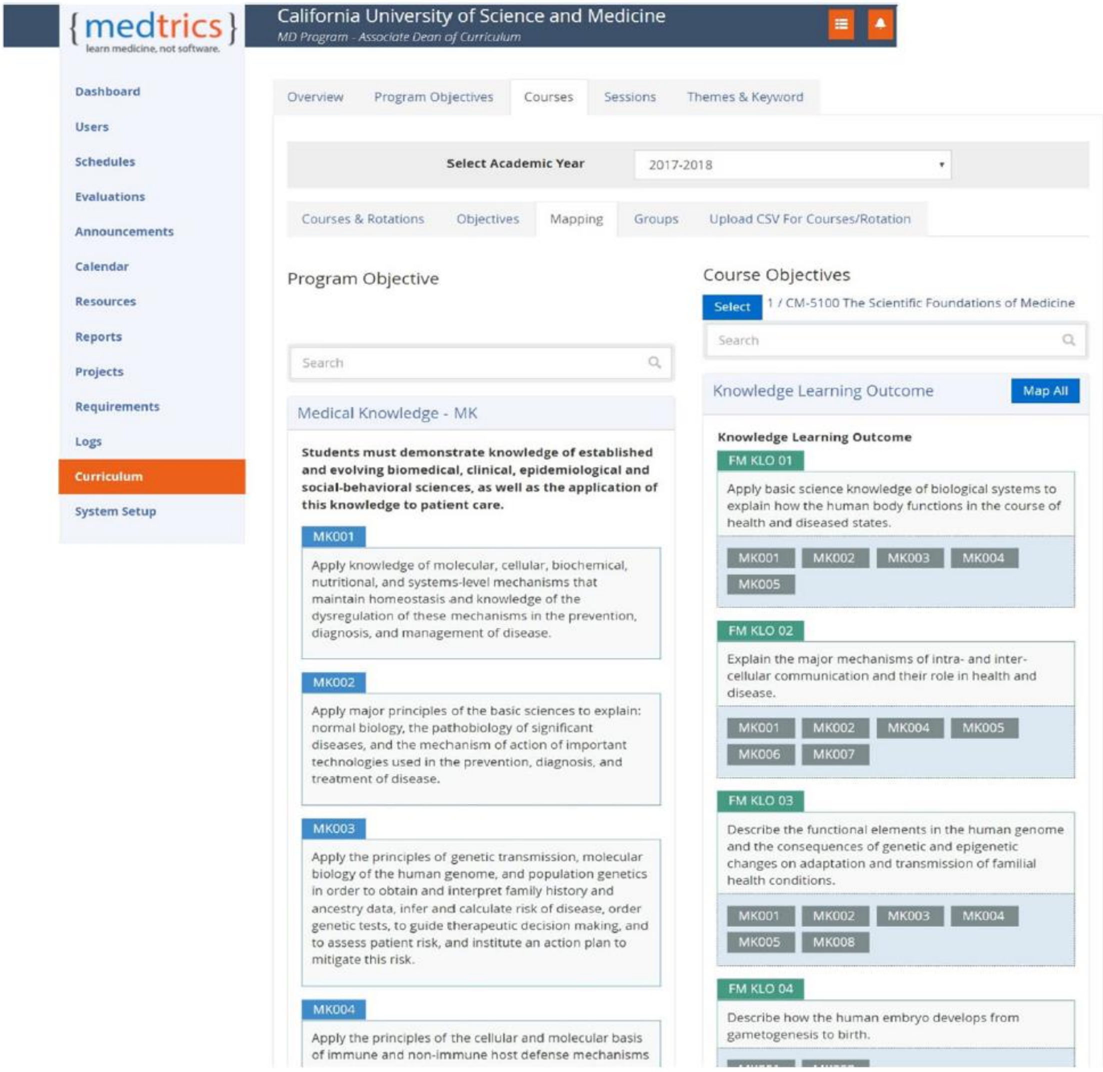

Fig. 3 Mapping of course level learning objectives to program level objectives by contrasting learning objectives in two columns and displaying addressed learning objectives as boxes/"bricks" as presented in the medtrics system. Source: [6]. License: CC-BY 4.0.

Komenda et al. [12] uses visualisation to show thematic associations between learning units in the curriculum. The Jaccard coefficient was selected as a measure of similarity. The graphical view presents as nodes MeSH terms that were used to tag individual elements of the curriculum. The size of the nodes shows the sum of associations between the nodes.

Constructive alignment is a relation of adequate arrangement of learning outcomes, learning activities and assessment tasks. Vaitsis et al. [21] proposed a set of three types of visualisations to inspect relations between those elements. All three views present the curriculum elements as nodes in an undirected graph. The radius of the nodes indicates weight of the elements in the curriculum (e.g. how often is a learning outcome addressed). The background colour of the nodes groups elements of the same type (e.g. red for learning outcomes, green for teaching methods). Edges between nodes are weighted, e.g. to indicate the success rate of students while being assessed on the given learning outcome. Fig. 4 shows a sample visualisation showing which learning methods are used to reach the given learning objectives.

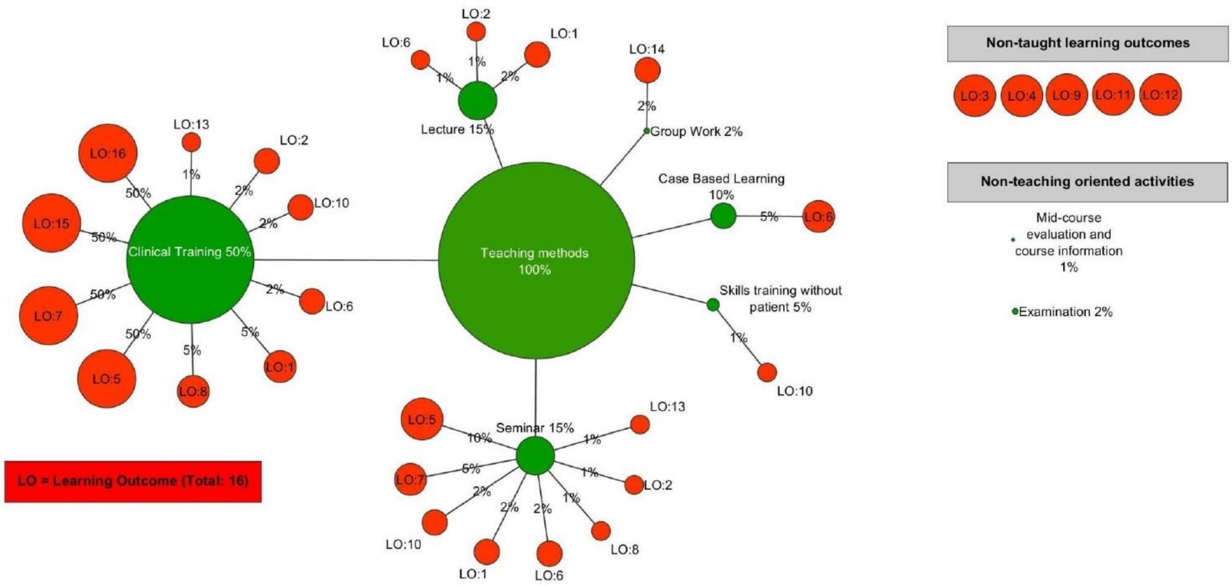

Fig. 4 A visualisation type to illustrate relation of teaching methods and individual learning outcomes in the curriculum. Source: [21]. License: CC-BY 4.0.

4.6 Possibilities to search by keywords

A crucial element of a curriculum mapping system is the keyword-based search functionality. For instance, Al-Eyd used this feature in reviewing course content for gaps and redundancies, as well as in checking for compliance of the course content with elements of the LCME standard [6]. Fig. 5 shows the result of a keyword query in the system medtrics.

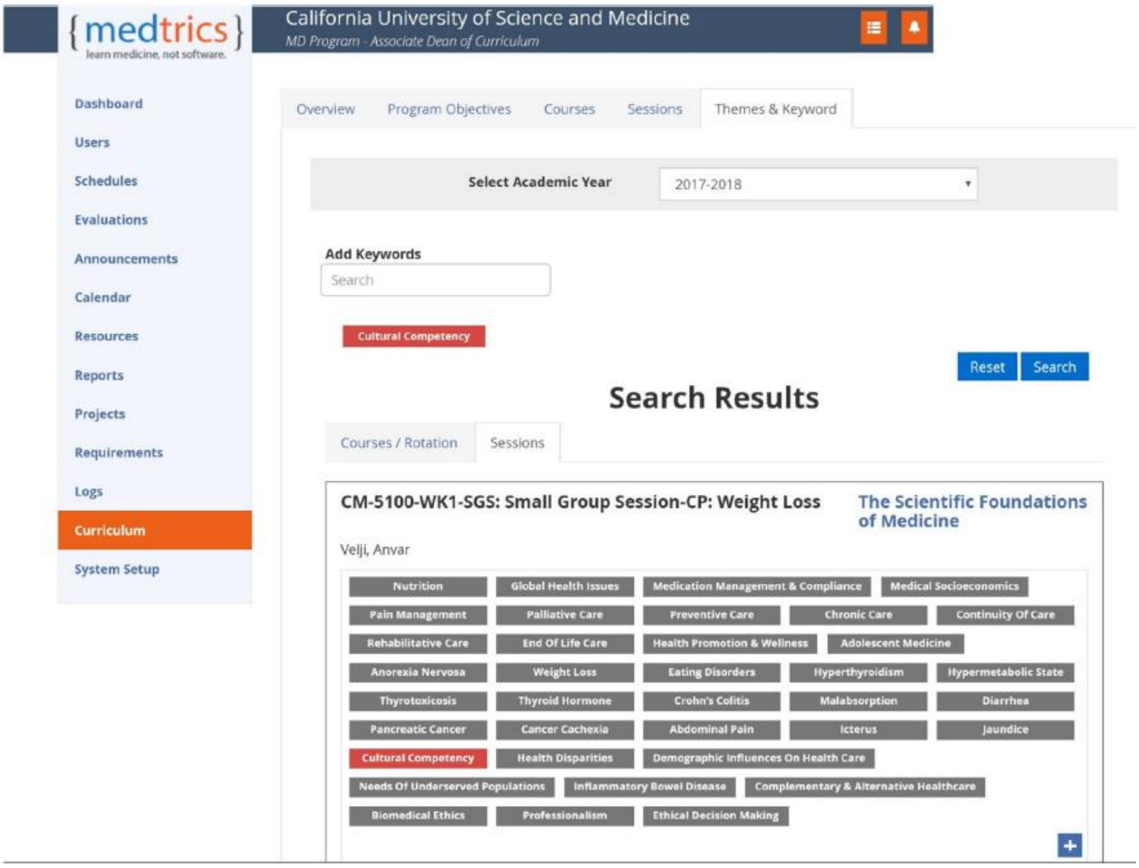

Fig. 5 Example of a keyword search functionality in the system medtrics.
Source: [6]. License: CC-BY 4.0.

As the human natural language is very divers containing many synonyms, near synonyms, and concept automatically associated by our cognitive capabilities, a successful implementation of keyword search requires support of technologies from the area of artificial intelligence. This includes the use of controlled vocabularies, thesauri and ontologies. When doing so it allows to consider in free-text searches synonyms and related (e.g. more specific) keywords from all connected vocabularies.

Spreckelsen et al. incorporated in their system a wide range of controlled vocabularies and classification systems including: MeSH, ICD10 and terminologies in use in Germany: OPS and IMPP-ID [2]. Authors of Prudentia [15] developed an interface with Unified Medical Language System (UMLS) which is a meta-thesaurus comprising over 100 controlled medical language sources (e.g. SNOMED, MeSH, WHO). Komenda et al., [12] after a scoping review of different terminologies and classification systems, decided to implement in their system the MeSH thesaurus. One of the reasons for that was the availability for this system of many regularly updated national editions including a Czech language version. In order to improve keywords searching Balzer et al. [5] suggested using structured vocabularies (e.g. verbs coming from a modification of Bloom's taxonomy [27]), descriptors (e.g. MeSH) and classification systems (e.g. ICD-10). Cottrell et al. [18] report using MedBiquitous terminology to standardize instructional methods, assessment methods and resources as well as USMLE Step 1 & 2 year-end profile reports to populate catalogues of tags to annotate curriculum description.

An additional feature that was recommend as helpful in keyword search was auto-completion of terms. For example, it has been used to describe learning objectives in the ACLO-Web [2].

4.7 Integration of international recommendations

In order to make the curriculum platform ready to use at international level, it should consider the need to implement local, national requirements. This involves awareness of national competency-based catalogues. These are catalogues proposed by organisations (governmental institutions (e.g. ministry of health or higher education), accreditation bodies, professional societies, etc.) that have the authority to set standards for all medical schools in a particular country. Such standards exist e.g. in Canada, United Kingdom, Germany or Poland. The support for national learning objectives catalogues is therefore an important feature of a versatile curriculum mapping system.

Below we present a short overview of the national medical learning objectives catalogues in Germany and Poland. The remaining three countries represented in the BCIME project: Czechia, Slovakia and Romania, have not yet established national competency-based learning objectives catalogues.

In Germany (including Austria and Switzerland):

The NKLM (Nationaler Kompetenzbasierter Lernzielkatalog Medizin) describes with learning objectives a core medical curriculum and, consequently the profile of a graduate. It is organised across subjects and organs and includes competencies, learning objectives and roles. The catalogue is available in German only at www.nklm.de.

The NKLM is structured in three sections: (1) Roles, (2) Knowledge, skills, and attitudes, and (3) Patient-centred health care, which are described in detail in the following paragraphs.

Section 1: Roles

The definition and description of the roles is based on the Canmeds framework [28] and includes seven roles (Tab. 4).

Tab. 4 Roles in NKLM catalogue

Role	Description	Number of entries
(5) Medical Expert	Physicians should become independent and responsible physicians and apply their knowledge, skills and professional attitude to provide a professional patient care.	Four chapters with 24 learning objectives
(6) Scholar	Physicians improve their action by lifelong learning and critical evaluation. They act as educators for students, patients, colleagues.	Four chapters with subchapters and 32 learning objectives
(7) Communicator	Physicians acknowledge the importance of communication for their daily practice. This includes respectful communication with patients, in interprofessional contexts, or with the public and also includes difficult situations.	Six chapters (Learning objectives are defined in chapter 14c "Communication in Healthcare"
(8) Collaborator	Physicians collaborate and communicate in interdisciplinary and interprofessional settings.	Four chapters with subchapters and 24 learning objectives

(9) Health advocate	Physicians promote a healthy lifestyle.	Three chapters with subchapters and 18 learning objectives
(10) Manager (Leader)	Physicians know the health system with its institutions and legal aspects. They apply quality improvement measures and show management competencies.	Ten chapters with subchapters and 37 learning objectives
(11) Professional	Physicians fulfil duties of a society and have to respect ethical rules and duties.	Four chapters with subchapters and 45 learning objectives

Section 2: Knowledge, skills and attitudes

This chapter is divided into 10 subchapters and includes aspects relevant for the role of the medical expert:

- Chapter 12: Principles of normal structures and functions
- Chapter 13: Principles of pathogenesis and pathomechanisms
- Chapter 14a: Medical-scientific skills
- Chapter 14b: Clinical-practical skills
- Chapter 14c: Communication in healthcare
- Chapter 15: Diagnostic principles
- Chapter 16: Therapeutic principles
- Chapter 17: Emergencies
- Chapter 18: Ethical, Historical and legal aspects
- Chapter 19: Health promotion and prevention

Section 3: Patient-centred healthcare

This section includes two chapters:

- Chapter 20: Reasons for counselling (symptoms)
- Chapter 21: Diagnoses

Structure of learning objectives:

Learning objectives are defined for section 1 and 2. Each learning objective has the following attributes (Tab. 5).

Tab. 5 Attributes of learning objectives in NKLM

Attribute	Description	Example
Chapter, subchapter	Chapter (see section 2) or role (see section 1)	13.2. "Students explain principles of pathogenesis." 13.2.1. "They explain reactions of adaptation, degeneration, and regeneration. They can..."
Id	Chapter.subchapter.id	13.2.1.1

Title / Description	Content of the learning objective	"explain the etiology, pathogenesis, and consequences of cell damage and cell death with examples."
Competency level – Basics ("Grundlagen")	1 = factual knowledge 2 = procedural knowledge 3a = action competency (under supervision) 3b = action competency (without supervision)	1
Competency level – Basis ("Basis")		1
Competency level - Final year		2
Competency level - continuing education		
Competency level - scientific competency		2
Cross references	Internally (id) or externally	-
Examples of use		"importance of senescent cells"
Reasons for counselling	Reference to chapter 20	-
Subject reference	Subjects based on the national subject catalogue that are related to this learning objective	"cross-disciplinary; OB/GYN, genetics, hygiene, microbiology, virology, pathology, pharmacology, toxicology, physics, physiology, dental medicine"

Entries in chapter 21 are structured as presented in Tab. 6.

Tab. 6 Structure of entries in chapter 21 of NKLM

Attribute	Description	Example
Chapter, subchapter		21.1.1 Primary organ system: Cardiovascular. Students have knowledge or action competency for diseases of the cardiovascular system.
Id	Chapter.subchapter.id	21.1.1.1.
Title / Description	content of the learning objective	Sepsis
Level	A (knowledge) or B (action competency)	B
Diagnostics	D - select, explain and apply correct diagnostic methods	D
Therapy	T - select, explain and apply correct therapeutic methods	T

Emergency	N - know what to do in an emergency situation (and apply under supervision)	N
Prevention	P - know, explain and apply measures for prevention	P
paediatric specificity	x - paediatric knowledge is required	x
rare disease	SE - a rare disease	-
cross references	internally (id) or externally	13.2.2; 13.2.6; 13.2.3; 13.2.7; 12.11.6.2; 12.12.1.2; 12.13.1.2; 12.15.3.7; 12.19.10.2; 12.11.6.2; 17.7; 17.6.1.9; 15.3.1; 15.2

The NKLM is used in German speaking countries as reference for curriculum mapping processes. Also, the new curriculum developed at the University of Augsburg is based on the NKLM.

In Poland:

Higher education system in Poland is regulated by the act Law on Higher Education and Science [29], which specifies professions that one is allowed to practice only after graduating from program that meets the Standards of Education (SoE) described by Ministry of Science and Higher Education. Most of healthcare professions are mentioned in this act (medicine, dentistry, pharmacy, nursery, midwifery, laboratory analytics, physiotherapy, paramedics) and have separate Standards of Education established jointly by Ministry of Health and Ministry of Higher Education and Science – available in Polish only [30].

Below are described SoE, using medicine studies as an example.

Standards of Education for medicine, implemented in 2012, consist of formal requirements (i.e. minimal total number of classes – 5700 hours), catalogue of learning outcomes and general description of the study program. There are 12 main learning outcomes divided into 3 categories:

A. Knowledge.

Student knows:

1. Development, structure and functions of human organism in physiology and pathology
2. Symptoms and progress of diseases
3. Diagnosis and treatments for specified pathologies
4. Ethical, social and legal aspects of medical profession and is aware of public health policies. Student's knowledge is based on Evidence Based Medicine

B. Skills.

Students can/ is able to:

1. Recognize medical pathologies and prioritise medical management
2. Diagnose life threatening emergencies
3. Plan diagnostic workup and interpret its result
4. Implement correct and safe treatment and anticipate its side effects

C. Social Competences.

Student:

1. Can maintain meaningful and respectful relation with patients
2. Applies patient-centred approach
3. Obeys physician-patient privilege and patient rights
4. Is aware about his or her limitations and aware about the need to continuously self-educate

These 12 main learning outcomes are followed by a list of 307 specific learning outcomes, which are grouped in 7 domains and assigned to either knowledge (W) or skills (U).

Tab. 7 Domains of learning outcomes in Polish Standards of Education

Code	Domain	Number of hours	Number of ECTS
A.	Morphological sciences	300	25
B.	Scientific basis of medicine	525	43
C.	Preclinical sciences	525	43
D.	Social sciences with elements of professionalism	240	12
E.	Clinical nonsurgical sciences	1060	65
F.	Clinical surgical sciences	900	50
G.	Legal and formal aspects of medicine	100	6
Final (6^{th}) year – workplace-based practice		900	60
Summer mandatory internships		600	20
Classes to be determined by university		550	20
	Sum	5700	344

As presented in Tab. 7, Polish Standards of Education determine minimal number of hours and ECTS points for each domain.

Each specific learning outcome is coded to reflect this structure, i.e. "C.U10. Student can interpret microbiology laboratory tests". This learning outcome is assigned as a skill (U) to preclinical sciences domain (C).

In addition to Standards of Education, there is a national catalogue of 143 explicit practical/ technical skills to be acquired by medicine (and dentistry) graduates, published by Ministry of Science and Higher Education [31]. Practical skills are divided into two categories, (broadly based on Miller's Pyramid):

A. Student performs skill correctly and fully independently
B. Student knows how the skill is performed and can assist with it

Catalogue of practical skills covers more procedures (and in more detail) than Standards of Education.

Standards of Education provide universities with liberty to design the structure of curriculum – it may be organised around discipline-based subjects (i.e. anatomy, pathology, cardiology), organ-based courses (i.e. cardiovascular) or fully integrated PBL-based modules. It is a responsibility of the university authorities to map the learning outcomes from national catalogues into local curriculum structure – each subject/course/module needs to be described with learning objectives - a syllabus. Universities are allowed to add their own learning outcomes or to subdivide national learning outcomes into more granulated objectives and put them in syllabi. For instance, medicine program at Jagiellonian University Medical College consists of 530 learning outcomes. This creates a complex structure that would need to be reflected in curriculum platform (Tab. 8).

Tab. 8 Two levels of learning objectives at Jagiellonian University

National level	Standards of Education: learning outcomes divided into 7 domains and 2 groups	Practical skills catalogue divided into 2 groups
Local level	Syllabus for each subject	

In Slovakia:

In the Slovak Republic, a system of study fields is specified for higher education. This system is issued by a decision of the Ministry of Education of the Slovak Republic and defines a detailed description for each study program taught either in 1st, 2nd, and/or 3rd study level. Tab. 9 shows the list of study fields classified into 9 groups (available in Slovak at https://www.portalvs.sk/sk/studijne-odbory).

Tab. 9 List of study fields in Slovakia

Group	*Study Fields*	*Number of Study Programs*
1. Education and training	1.1 Teaching, tutoring and educational sciences	1169
2. Humanities and art	2.1 Humanities 2.2 Art	804 131
3. Social, economic and legal sciences	3.1 Social and behavioural sciences 3.2 Journalism and information 3.3 Economics and management 3.4 Law	503 107 353 134
4. Natural sciences	4.1 The science of inanimate nature 4.2 Living nature sciences 4.3 Ecological and environmental sciences	254 76 102
5. Design, technology, production and	5.1 Architecture and construction	133

communication	5.2 Engineering, technology, production and communication	783
6. Agricultural and veterinary sciences	6.1 Agriculture 6.2 Forestry 6.3 Veterinary sciences 6.4 Water management	101 32 12 3
7. Health	7.1 Medical sciences 7.2 Dentistry 7.3 Pharmaceutical Sciences 7.4 Health care sciences	67 7 4 140
8. Services	8.1 Personal services 8.2 Transport and postal services 8.3 Security services 8.4 Defence and military 8.5 Logistics	52 6 52 16 10
9. Computer science, mathematics, information and communication technologies	9.1 Mathematics and statistics 9.2 Computer science, information and communication technologies	58 120

The study fields relevant for the project are General medicine and Dentistry coded as 7.1.1 and 7.2.1 respectively. Graduates of the doctoral study program in the field of study General medicine are qualified to perform the profession general practitioner with academic title “doctor of medicine” (MUDr.). The graduate of General medicine has the theoretical knowledge of all theoretical, pre-clinical and clinical disciplines and has mastered basic diagnostic, therapeutic and preventive procedures in practical training and is able to apply them in his/her profession to understand the existence and significance of the links between clinical medicine and its scientific basis. The study field General medicine is required by EU Directive 93/16/EC to prepare a regulated medical profession in the range of 5,500 hours of study, as well as by Slovak legislation to acquire professional competence for the category of doctor.

The legislation specifies the core topics of General medicine study field. These are covered by:

- Theoretical subjects (1st stage of study): anatomy, histology and embryology, biophysics, medical chemistry and biochemistry, medical biology, physiology.
- Preclinical subjects (2nd stage of study): pathological anatomy, pathological physiology, microbiology and immunology, pharmacology, epidemiology, hygiene, medical psychology, medical ethics.
- Clinical Subjects (3rd phase of study): internal medicine, surgery, paediatrics, gynaecology and obstetrics, pneumology, occupational medicine, infectology, haematology and transfusion, neurology, psychiatry, dermatovenerology, anaesthesiology, traumatology and orthopaedics, urology, neurosurgery, plastic surgery ophthalmology, otorhinolaryngology, dental surgery, clinical oncology and radiotherapy, radiodiagnostics and nuclear medicine.

Knowledge in the core of knowledge must be part of the content of each curriculum in this field of study. Thus, the study program must cover the entire content of the field of study. At least 1/2 of the curriculum content must include topics (core and other) of the field of study, in 100% of the ECTS credits of the field.

Similarly to the General medicine, the graduates of the study field Dental medicine are qualified to perform the profession of dentist with academic title "Medicinae dentale doctor" (MDDr.). Within the parameters of clinical competence as part of a comprehensive patient care and maintenance system, the dentist is able to work independently in the oral cavity, and the required level of his/her knowledge must be consistent with EU Directive No.78/686/EEC accepted by Ministry of education in Slovakia.

Core topics of the Dentistry (Dental medicine) must be covered by:

- morphological and physiological disciplines: macroscopic and microscopic anatomy, molecular biology and genetics, biochemistry, physiology
- preclinical disciplines (to understand and influence disease processes): pathological anatomy, pathological physiology, microbiology, immunology, pharmacology
- preclinical dentistry, dental materials and technologies
- dental clinical disciplines, including diagnostic (to influence and maintain facial health): preventive dentistry, radiology, conservative dentistry and endodontics, dental prosthetics, dentoalveolar and maxillofacial surgery, periodontology, pedostomatology, orthodontics, therapeutic dentistry
- clinical general-medical disciplines, which are closely related to general diseases, significantly influence the subject of the study field, guarantee its medical character and connection with the whole organism: internal medicine, surgery, neurology, dermatovenerology, infectious medicine, paediatrics, psychology and psychiatry ophthalmology, otorhinolaryngology

The study programs in both above mentioned study fields (2nd level of university studies) are of a standard length of 6 years and contain 360 ECTS credits. Although there is a detailed catalogue of the study fields and requirements in their study programs, the national catalogue of learning objectives is not established yet (as mentioned earlier). However, each institution has to summarise all the details of particular course through standardized syllabus of the course (see Appendix 1).

4.8 Possibility to modify reports and outputs according to the institutional requirements

A survey conducted by Timothy Willett on the use of curriculum mapping software in Canada and UK returned a large number of different custom-built solutions [26]. CurrMIT, which is the centralised curriculum mapping system in use by all North American medical schools, has been often criticised as not flexible enough and therefore many schools designed or purchased in addition to that their own systems to address their local needs [32]. This suggests that prospective curriculum mapping systems should enable customisation of its functionality depending on local institutional needs.

Adaptation to institutional requirements may involve using easy to exchange and update institutional and national learning objectives catalogues at different levels of granularity (as discussed in 4.5 and 4.7). Another possibility could be the support of national languages of the user interface. Systems as LOOOP, MER*LIN* and ACLO-Web are available in German, the OPTIMED system is available in Czech language. Yet, the use of local language or jargon is important in gaining acceptability and overcoming innovation resistance. Even in countries using one language (as in Germany), some of the systems (e.g. MER*LIN*) enable installation of site-specific terminologies by local administrators [7].

Some of the systems allow the community around a tool to collaboratively create their institutional vocabularies (e.g. learning objectives catalogues) [2,22]. A good example for that is the ACLO-Web system [2] built on top of a MediaWiki platform which enable extending the list of learning objectives in a Wiki-style to create a user-generated description of the curriculum (folksonomy).

Characteristic for an institution may be different curricular models, the structure of subjects, breakdown of organisation into departments, unique features or strengths of the curriculum as interdisciplinarity. An interesting feature is offered by the LOOOP software package which enables adding to the curriculum map teaching capabilities of an individual department, and even statistical distribution of patient availability [5]. These data are in that way ready to be considered in the local institutional planning process.

Spreckelsen et al. [2] recommend that a curriculum mapping system should have two types of views: predefined overviews and the possibility to specify detailed bespoke queries from building blocks of the curriculum. This was facilitated by the use of Semantic Web technologies. The MediaWiki platform in use by Spreckelsen et al. enables easy extension of the online data entry forms (so far 13) and forms for flexible searches (so far 4).

4.9 Evaluation of learning objectives

In addition to national learning objectives catalogues discussed already in 4.7, there are discipline specific learning objectives catalogues. Even when in some countries, like in Germany, the discipline specific catalogues were to a great extent made obsolete by a centrally managed, holistic national learning objectives catalogue (NKLM for German-speaking countries), there is still some potential space for use of discipline specific catalogues that could warrant consideration of their use in the curriculum mapping platform. The first reason is that in case of international mapping activities, as planned in the BCIME project for the discipline of anatomy, national catalogues might be problematic as different countries use different catalogues, and a discipline catalogue could help in the mapping activity. This could be also a solution for those countries were no national catalogues are available. Finally, due to a broad-scope of national catalogues, they are often not fine-grained enough to be useful for a detailed description of specific sets of skills (e.g. as is the case for communication skills learning objectives in the Polish national catalogue).

Learning objective catalogues in anatomy

"Anatomy has historically been a cornerstone in medical education regardless of nation, racial background, or medical school system." [33].

The importance of anatomy has been recognised in the main documents, defining learning outcomes for medical graduates. In the Tuning project for Medicine [34] – a result of the initiative on the European Commission, serving harmonisation of the European Higher Education - one can read that "Graduates from medical degree programmes in Europe should be able to demonstrate knowledge of (…) normal structure (anatomy)."

Slightly less general, but still not granular, anatomical outcomes were described in the Outcomes for graduates [35] – a document presenting principles of teaching medicine at the undergraduate level in the UK. It is stating: "Newly qualified doctors must be able to apply biomedical scientific principles, methods and knowledge to medical practice and integrate these into patient care. This must include principles and knowledge relating to anatomy (…). They must be able to (…) explain how normal human structure and function and physiological processes apply, including at the extremes of age, in children and young people and during pregnancy and childbirth."

Despite the fact, that in the second document one may observe an emphasis on the application of the knowledge, not just its possession, lack of the anatomical knowledge of medical graduates persisted an important problem. Another factor leading to the recognition of the need for the detailed description of the anatomical curriculum is the fact that, in recent years, in most universities, we may observe changes in the curricula. Greater integration of the teaching and emphasis on the clinical context of the medicine resulted among others in the limitation of hours dedicated to anatomical education and division this science to organ-based subjects [36].

There have been several attempts to define a core detailed syllabus in anatomy. Several propositions were assessed as either too detailed or too specialised for medical graduates [37,38]. The process of defining the minimum knowledge in the field of topographical anatomy has not finished yet and documents are evolving – as are evolving medical curricula in the world. It reflects the debate which amount of the knowledge of basic sciences is enough deep and broad for a medical practitioner at the beginning of his/her career path.

Documents, which are existing nowadays, could be divided into two types – dedicated to a singular anatomical region or complete human body. Papers presented under the auspices of the International Federation of Associations of Anatomists (IFAA) represents the first one. Up to this day, there were developed and published four syllabi, dedicated to different regions of the human body. Namely:

- A Core Syllabus for the Teaching of Neuroanatomy to Medical Student [36]
- A Core Syllabus for the Teaching of Head and Neck Anatomy to Medical Students [39]
- A Core Syllabus for Teaching Musculoskeletal Anatomy of the Vertebral Column and Limbs to Medical Students [40]
- A Core Syllabus for the Teaching of Embryology and Teratology to Medical Students [41]

At the other end of the spectrum, there is a slightly more general document enclosing whole anatomy, prepared on a basis of the UK and Ireland core syllabi by the members of the Council and the Education Committee of the Anatomical Society – The regional anatomy syllabus for undergraduate medicine [42].

Learning objective catalogues in communication skills

It is well known that communication skills are essential for all health professionals. Over the last 20 years there has been an increase in research on communication skills and teaching of these skills is explicitly included in medical programs more and more often [43].

At the beginning, it is worth mentioning that healthcare communication is unique, complex and nuanced. Although communication skills can be undoubtedly taught, there are doubts whether, due to the complexity of this process, it is possible to position communication as a set of behavioural skills and learning objectives. Some authors argue that such an approach is reductionistic and "atomisation of communication into discrete observable skills (learning objectives) may not take into consideration the complexity of communication interaction and does not consider the authenticity and creativity required in practice" [44].

The first catalogue of common core learning objectives in medical education was introduced after the Bologna Declaration as part of The Tuning Project for Medicine-learning outcomes for undergraduate medical education in Europe [34]. The learning objectives in this document are grouped in three sections. The first section - Level 1 comprises twelve general outcomes. The second section - includes, under each Level 1 outcome, a series of Level 2 outcomes. The third section consisted of generic outcomes for Higher Education that encompass many aspects of professionalism.

In The Tuning Project for Medicine catalogue, one outcome of level 1 is entirely devoted to medical communication skills “Communicate effectively in a medical context” and contains 10 detailed outcomes. Additionally, the outcome of 'Carry out a consultation with a patient' contains two more detailed outcomes regarding communication.

Among other well-known catalogues of medical skills for graduates is the latest British General Medical Council “Outcomes for graduates 2018”. As the authors of this document claim, this set of standards can serve as “a basis for medical schools to develop their curricula and programs of learning and a blueprint or plan for assessments at medical schools” [35]. This learning outcomes catalogue consists of three parts: professional values and behaviours, professional skills and professional knowledge. Most outcomes regarding communication are in group ”professional skills”, but some of them are also in group “professional values and behaviours”.

While the above described documents referred to learning outcomes for a wide range of doctor's or graduate's skills (not only communication skills), there is also “A European consensus on learning objectives for a core communication curriculum in health care professions” [45]. This catalogue lists 61 educational objectives and was agreed on by 121 communication experts from 16 countries and 15 professions. It was translated into German and adapted to German [46].

Also in 2016 “A Latin American, Portuguese and Spanish consensus on a core communication curriculum for undergraduate medical education” was developed and published [47]. In this study 46 experts from 8 countries worked on a list of clinical communication learning outcomes, and a consensus was reached on 136 learning outcomes grouped under 6 competency domains.

While writing about learning objectives catalogues it is worth mentioning the latest Denniston’s systematic literature review on learning outcome for communication skills [48]. In this study authors reviewed 168 papers from which they extracted 1669 learning outcomes, then refined them using qualitative synthesis to finally arrive at 205 outcomes that were grouped into four domains: knowledge, content skills (what is communicated), process skills (how one communicates) and perceptual skills (awareness of self and others and how that impacts communication).

Learning objectives in Analysis, Data Management and Informatics for Healthcare Specialisation

Behrends et al. [8] mapped medical informatics learning objectives from the NKLM (German National Medical Competencies Catalogue) to identify common ground between the medical informatics and the medical curriculum in Germany. The learning objective catalogue of Medical Informatics was GDMS “Medical Informatics” for undergraduate medical education [49]. The mapping process was supported by the MER*LIN* platform.

Learning objectives on Conservative and Prosthetic Dentistry

The topic of computer-aided curriculum mapping in dentistry is tackled in the study by [4]. The electronic thematic map developed at The University of Iowa College of Dentistry uses three catalogues of target competencies: two of them are local (characteristics of a graduate from The University of Iowa College of Dentistry and Dental Clinics; and school's competencies). The third catalogue in use is CODA (Commission on Dental Accreditation): a US national standard for dental schools [50].

The National Competence Based Catalogues of Learning Objectives for Undergraduate Dental Education (NKLZ, www.nklz.de), similar to above mentioned NKLM, is available in German speaking countries as published by Fisher et al. [51]. The catalogues describe the competencies students of dental degrees in Germany should have acquired by the time they graduate.

Bateman et al. [52] described problems of using learning outcomes in dental education. They argue that if one understands the background, construct and intended purpose of learning outcomes, then it is possible to write them so that they can actually be applied and therefore used effectively. The General Dental Council (GDC) established in the United Kingdom is the statutory regulator and its primary purpose is to protect patient safety and maintain public confidence in dental services. Except of others, they set standards for providers of dental education and training in the UK. In their documents, produced as the results of the work on Standards for education [53] the learning outcomes are specified. Learning outcomes are subdivided for dentists, dental therapists, dental hygienists, dental nurses, orthodontic therapists, clinical dental technicians, and for dental technicians. All these categories have outcomes grouped in four domains: clinical, communication, professionalism, and management and leadership.

Mahmoodi et al. [54] established an Catalogue of Interactive Learning Objectives of the University Clinic of Mainz (ILKUM) where the hierarchical structure is designed according to the Association for Dental Education in Europe (ADEE) levels of competence. ADEE subdivide the teaching schedule for dental education into three ascending competence levels: Level I: "Be familiar with": The student must be aware of basic theoretical knowledge, but no practical skills are required, Level II: "Have knowledge of": In addition to sound theoretical knowledge, basic practical experience as well as basic practical capabilities are required, and Level III: "Be competent at": The student must possess strong theoretical and practical knowledge.

There is no evidence of learning objectives catalogues for dentistry existence in other BCIME project partner countries except Germany and Poland. However, the majority of the medical universities and faculties offering education in the field of dentistry respect and implements rules aligned with directive 2013/55/EU amending directive 2005/36/EC. Basic dental training shall comprise a total of at least five years of study, which may in addition be expressed with the equivalent ECTS credits, and shall consist of at least 5 000 hours of full-time theoretical and practical training that comprises at least the study programme for dental practitioners. This program include A. Basic subjects (Chemistry, Physics, Biology); B. Medico-biological subjects and general medical subjects (Anatomy, Embryology, Histology, including cytology, Physiology, Biochemistry (or physiological chemistry), Pathological anatomy, General pathology, Pharmacology, Microbiology, Hygiene, Preventive medicine and epidemiology, Radiology, Physiotherapy, General surgery, General medicine, including paediatrics, Oto-rhino-laryngology, Dermato-venereology, General psychology - psychopathology, neuropathology, Anaesthetics) and C. Subjects directly related to dentistry, Prosthodontics, Dental materials and equipment, Conservative dentistry, Preventive dentistry, Anaesthetics and sedation, Special surgery, Special pathology, Clinical practice, Paedodontics, Orthodontics, Periodontics, Dental radiology, Dental occlusion and function of the jaw, Professional organisation, ethics and legislation, Social aspects of dental practice). The syllabi of these subjects are individually described by particular university/faculty.

Learning objectives in clinical skills

Clinical skills for German speaking countries are best characterised by a subset of the national NKLM catalogue. The relevant part for that is chapter 14b.

Learning objectives in neurosurgery

In Romania there is no national learning objectives catalogue and each university creates its own list of requirements that have to be accomplished. Consequently, the learning objectives will be described below are strictly specific to the Neurosurgical department of the University of Medicine and Pharmacy "Grigore T. Popa" from Iasi.

This elective rotation in Neurosurgery is a four (4) week experience in the management of injury and illness of the neurologic system. The student may be required to travel to the clinic, outpatient surgery centre and/or hospital facility during his/her rotation time. Many students electing this rotation will be in their third or fourth year of osteopathic medical school. A post–rotation examination is not required.

Medical knowledge

The Neurological Examination

1. Evaluate patient's mental status and speech.
2. Examine the cranial nerves.
3. Examine central and peripheral sensory function.
4. Examine motor function.
5. Examine cranial and peripheral reflexes.
6. Examine cerebellar function and gait.

Fundamentals of neuroimaging

1. Recognize common spine fractures and dislocations.
2. Differentiate on computerized images between blood, air, fat, CSF, and bone.
3. Distinguish the typical imaging characteristics of epidural hematoma, acute subdural hematoma, chronic subdural hematoma, intracerebral hemorrhage, and subarachnoid hemorrhage.

Intracranial hypertension

1. Define cerebral perfusion pressure, and explain how it is used in the management of patients with elevated intracranial pressure.
2. Describe how blood gases, fluids, and electrolyte balance influence intracranial pressure.
3. Describe the clinical manifestations of acute brain herniation, including transtentorial, uncal, and subfalcine herniation syndromes.

Diagnosis and management of ischemic cerebrovascular disease

1. Distinguish the symptoms and signs of anterior and posterior circulation ischemia.
2. Differentiate the radiographic presentations of the different types of ischemic stroke: embolic, hemodynamic, and lacunar.

3. Describe the roles and indications of the following treatment options in ischemic disease: medical management, risk factor modification, and surgical therapy.

Diagnosis and management of nontraumatic neck and back problems

1. Define radiculopathy, myelopathy, and cauda equina syndrome.
2. Describe the general management of cervical disc herniation, lumbar disc herniation, lumbar instability, and low back pain.
3. List the most common examples of extradural, intradural-extramedullary, and intramedullary spine tumors.

Patient care

The neurological examination

1. Evaluate patient's mental status and speech.
2. Examine the cranial nerves.
3. Examine central and peripheral sensory function.
4. Examine motor function.
5. Examine cranial and peripheral reflexes.
6. Examine cerebellar function and gait.

Diagnosis and management of head trauma

1. Assign the Glasgow Coma Score.
2. Initiate management of elevated intracranial pressure in head trauma.
3. Define concussion, brain contusion, and diffuse axonal injury, and initiate management of each.
4. Distinguish anatomically and radiographically acute subdural and epidural hematoma, and describe the surgical indications for each.
5. Describe the initial management of penetrating high and low velocity head trauma.
6. Describe the management of chronic subdural hematoma.

Diagnosis and management of brain tumour and abscess

1. Know the relative incidence and location of the major types of primary and secondary brain tumours.
2. Describe the general clinical presentations of brain tumours in the following locations: cerebral hemisphere, cerebellum, brainstem, pituitary, and cerebellopontine angle.
3. List the advantages and limitations of the following diagnostic tools used in the evaluation of brain tumours: CT, MRI, MR spectroscopy, and angiography.
4. Describe the surgical indications for the most common benign and malignant tumours in the locations listed in #2.
5. Describe the indications for and the differences between radiotherapy and radiosurgery in the treatment of malignant brain tumours.
6. List the major differences between the diagnosis and management of brain tumour and abscess.
7. List the most common aetiologies of cerebral abscess.

Diagnosis and management of headache

1. Distinguish the radiographic presentation of the major causes of intracranial haemorrhage: hypertensive intracerebral haemorrhage, amyloid intracerebral haemorrhage, subarachnoid

haemorrhage, arteriovenous malformation haemorrhage, tumour haemorrhage, and coagulopathy haemorrhage.
2. Apply the following diagnostic tools in evaluation of acute headache (CT, MRI, angiogram, and lumbar puncture).
3. Describe the broad treatment strategies (surgery, radiosurgery, interventional radiology, as well as treatment of vasospasm) of intracranial aneurysms and vascular malformations.
4. Differentiate the symptomatology of migraine, cluster, tension, and sinusitis headache.

Spinal trauma

1. Describe the rapid assessment of a patient with spinal trauma.
2. Recognize the common spine fractures on X-ray.
3. Initiate acute management of spinal cord injury, including immobilization, steroids, and systemic measures.
4. Define the unstable spine.

Interpersonal and communication skills

OBJECTIVES: Interpersonal and Communication Skills

1. Communicates effectively with attending, resident, team members and other health care professionals.
2. Documentation in medical records is legible.
3. Communicates appropriately and professionally to patient and family members.
4. Demonstrates ability to develop and execute patient care plans appropriate for level of training and follows the SOAP/problem oriented format.

Case presentations

1. Present a case to your preceptor, including relevant history, neurological examination, imaging findings, and treatment plan.

Participation on the wards

1. Ask neurosurgical staff (residents, attendants, etc.) questions as appropriate to enhance learning opportunities both in and out of the OR.

Professionalism

OBJECTIVES: Professionalism

1. Demonstrates a commitment to continuity of patient care.
2. Displays a sense of responsibility and respect to patients, families, staff and peers.
3. Demonstrates cultural sensitivity.
4. Maintains a professional appearance, well groomed, appropriately dressed.
5. Punctual in attendance, prompt and available when called upon.
6. Motivated to learn, shows appropriate assertiveness, flexibility, adaptability toward education.
7. Demonstrates appropriate attitude, cooperative, receptive to feedback.
8. Introduce self to those who you are working with, the patient, attending, resident, other physicians, nurses, staff, etc.

Operating room

1. Demonstrate professionalism in the operating room; do not be disruptive, but feel free to participate, including asking questions, reviewing images, pathology, intraoperative findings, etc.
2. Demonstrate level of interest by scrubbing in on cases at the discretion of the resident and attending.

Conferences

1. Attend all scheduled conferences.
2. Feel free to participate and ask questions.

4.10 Identification of redundancies [and gaps] in learning objectives

One of the problems that is hoped to be solved by curriculum mapping is the identification of gaps and redundancies in the curriculum. Considering that a study programme can contain even more than 7000 learning objectives [12], the human capabilities to recognise in such complicated structure missing outcomes or unintended repetitions is very difficult, laborious and sometimes even impossible.

The first step in identification of such issues is to get a good overview of the curriculum which was already described in 4.2. Fundamental is also an implemented keyword search functionality (as described in 4.6). But there are also specialised solutions building on the basic functionality to highlight the issues.

For instance, the curriculum mapping system Prudentia [15] uses a five-level competency framework. The hierarchical relations are checked top-down from the highest (macro) level of accreditation standards down to specific learning objectives of individual learning sessions (micro level). If at any stage a link to the lower level in the hierarchy is missing, the higher level outcomes are marked with red hazard sign flags. This draws attention to the gaps in implementation of the required competencies and by that identifies areas that require further attention and proper alignment.

In the electronic thematic map of the University of Iowa College of Dentistry curriculum planners may select competencies from three sets by locating them in drop-down menus [4]. After selection of a competency a table is displayed, showing in rows all the courses in which this competency was addressed, assessed formatively or summatively and in what form did it happen (columns of the table) [4]. This allows identification of gaps and redundancies in the curriculum.

A balloon chart can by the presence and size of the round shapes help in visualising if and how intensive a particular learning objective is addressed in the curriculum across semesters (e.g. presented in [7]). This format can also be used to show the assessment profile (presence and intensity in assessment of achieved learning objectives). Gaps in this view may be easily spotted in places with missing circular shapes.

Cottrell et al. [18] recommend formation of threads through the curriculum. By threads are meant “important content areas that should be advanced across the curriculum to benefit student learning”. Examples are given that include: radiology and ultrasound, oral health and healthcare disparities. “Thread directors” are appointed to identify gaps and redundancies in implementation of the thread.

Curriculum mapping visualisations by Vaitsis et al. [21] have also a section for unaddressed learning outcomes. That way, even though the elements are not related to any other element in the graph, they are still displayed in order not be left out of the analysis. They are automatically grouped in the following sections: a) Non-taught learning outcomes in teaching methods; b) Non-examined learning outcomes in written examination; c) Examined but non-taught learning outcomes. Low scores is in the assessment weights of the graph show those topics in which students perform poorly and need to be strengthened in the curriculum (Fig. 6).

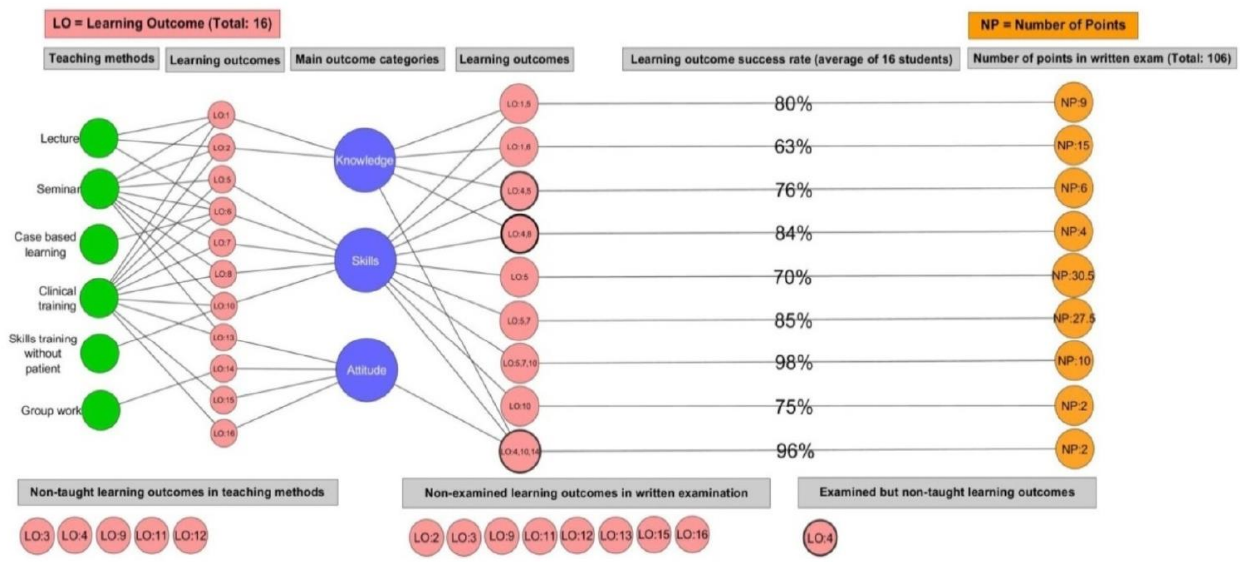

Fig. 6 Curriculum gap analysis visualisation in the study by Vaitsis et al.
Source: [21]. License: CC-BY 4.0.

4.11 Outcome-based education compatibility

Outcome-based education/training is education with an emphasis on the end product [55]. In medicine these are the qualities of well-trained doctors. As Steketee has formulated it describing their curriculum mapping system: Prudentia is outcomes-based meaning “the statements in each level identify what students will have achieved at the end of a period of time” [15].

The role of the curriculum mapping software in outcome-based education process is to show how well recognised exit outcomes have been addressed in the curriculum. The curriculum mapping systems LOOOP and MER*LIN* are outcome-based compatible as they are grounded in a widely accepted competency-based learning objectives catalogue NKLM. The LOOOP system [5] visualises learning objectives according to the respective category of Anderson’s 24-square-table [27] and to respective Reporter-Interpreter-Manager-Educator (RIME) roles [56]. Vaitsis et al. use in their visualisation learning outcomes of the Swedish Higher Education Authority learning outcomes for undergraduate medical education as a reference competency framework [21]. The curriculum mapping system CLUE is based on competency frameworks of UK’s General Medical Council (GMC) and Accreditation Council for Graduate Medical Education (ACGME) [3], Schneider et al. use Commission on Dental Accreditation (CODA) standards [4], Prudendia refers to AMC Student Outcomes for Australia and New Zealand [15].

Another way of facilitating outcome-based education compatibility in curriculum mapping software is to employ a structured entry of new learning objectives. In the OPTIMED system this is achieved by enabling the user to select action verbs for the statements in accordance with the recommended vocabulary of Bloom’s taxonomy [13]. Moreover, achieving comparability of outcome-based education quality across Europe sounds also quite challenging. The MEDCIN project [58] (http://www.medcin-project.eu) is focused on curriculum related data standards in real medical and healthcare education processes. MEDCIN has developed a unified platform supporting widespread technical standards (guaranteed by MedBiquitous Consortium, the leading organization in the development and promotion of technology standards for the health professions), which is fully in compliance with the proven theoretical background (series of outcome-based agreements the at European higher education area commonly known as Bologna Process). The MEDCIN platform provides powerful online tools for standard-compliant curriculum import, overview and comparison using the following features: summary report, building blocks' context, search by keyword and advanced text analysis.

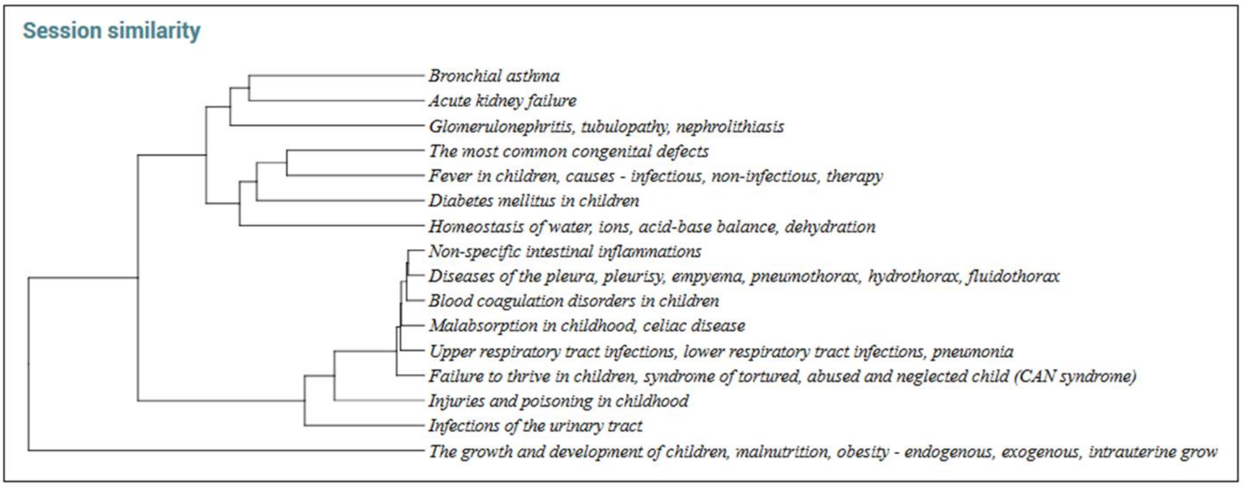

Fig. 7 Dendrogram of keyword-based analysis representing similarities between particular lessons in Paediatrics - State Exam course, which is taught at Masaryk University.

4.12 Complex reporting based on available curriculum building blocks

Complexity is an intrinsic part of the analysis of medical curricula because of the great number of elements to consider and their high degree of interconnectedness. For that reason there is a still growing demand for dynamic systems that can facilitate more efficient curriculum management at different levels [32]. However, the complexity of computational analyses should not come at the expenses of low usability. According to Harden, the two important attributes of any curriculum map should be communicability and transparency [24]. Yet, there is the risk that unwieldy user interfaces may discourage the users from curriculum mapping. A potential danger is that poorly designed or overloaded reports can deliver an unclear picture. Too many elements may overshadow the viewpoint of the analysed aspects of the curriculum [6].

Spreckelsen et al. recommend to introduce formative usability studies in the development process of curriculum mapping software [2]. They have proposed seven hypothetical scenarios (user stories) involving both students and medical teachers to be performed by test users. The number of usability testers does not have to be large: 5-8 could be sufficient. In their study a small group of testers provided precious comments that directed development of the software tool. In line with that, Schneider et al sees improvements in usability as a next step in development of their system [4].

Another point that adds to the burden of using curriculum mapping software is the effortful data entry process. In a survey conducted by Willett high demand on human resources was the most frequently mentioned challenge in curriculum mapping [26]. Fritze et al. [7] recommend to address this issue by reducing the number of mapping criteria (e.g. by limiting the number of implemented Harden's windows [24]). Cottrell et al. recommend as motivational factor to provide visual progress updates of the mapping process. It was regarded as helpful for the faculty to see, as time went by, what was being accomplished in the curriculum mapping process [18].

Finally, it is recommended to semi-automatize the reporting process. For instance, Al-Eyd et al. generate pre-filled session mapping templates (Fig. 8) to save the mappers lot of time spent on unnecessary data entry [6].

California University of Science & Medicine-School of Medicine (CalMed-SOM)
"Session Plan Template" (Flipped Classroom Session Version)

Course Title		Course Code		Course Credit		Course Duration (Wks)	
Clinical Presentation							
Students (MS1-MS4)		Learning Location (Site/Venue/Setting)					
Session Title							
Week/Session Sequence Code (A-N)		Length of Voice Over PowerPoint Recorded Session	45 Min	Length of Flipped Classroom Session	30 Min		
Instructor (s)							
Keywords							
Instructional Method*/ Mode of Delivery	Lecture (Primary) Discussion-Large Group		Resource Type*	Audience Response System; Educational Technology, Clinical Case			
Active Learning Experience	Flipped Classroom; Small Group Session (Short Case Version of PBL)						
Formative Assessment*/In Class Assessment(s)	Exam - Institutionally Developed, Written/ Computer-based; Narrative Assessment; Participation; Self-Assessment						
Summative Assessment*	Exam - Institutionally Developed, Written/ Computer-based						
Objectives/Outcomes**: *CLO=Course Learning Outcomes. As you list your SLOs of this session, please indicate the link to the appropriate CLO(s) of Knowledge (K), Skills (S), and Attitude (A).*	Session Learning Objectives/Outcomes (SLOs):					CLO #	
	1.					K	
						S	
						A	
	2.					K	
						S	
						A	
	3.					K	
						S	

Fig. 8 A way of reducing complexity of curriculum management is generation of data entry templates with pre-filled content (highlighted in yellow). Source: [6]. License: CC-BY 4.0.

In the MER*LIN* system reduction of data volume is achieved by characterising teaching at sub-competency level with ticking off the underlying objectives is taught instead of selecting them from a long drop-down list or typing them in manually [7].

4.13 Step-by-step manual how to implement the requested changes

While going through the collected literature on curriculum mapping software, we paid also attention to the applied software engineering model.

Some of the developers employed a waterfall model with consecutive phases clearly defined. Fritze et al. [7] followed implementation of the MER*LIN* system in seven steps: 1. Needs assessment; 2. Identification of common mapping key components and their structures; 3. Modelling database architecture; 4. Programming; 5. Feasibility assessment; 6. Implementation; 7. Database adaptations. Balzer et al. described a nine-year long process of development, implementation and evaluation of their LOOOP curriculum mapping system, which consisted of three phases: 1. Needs assessment and development; 2. Analysis of the effects of implementation; 3. Evaluation of current usage statistics [5].

In other systems, the dynamic software engineering methods were applied. For instance Steketee [15] reported the use of an *agile* approach to curriculum mapping system (iterative process of planning, building and testing against requirements). OPTIMED was implemented using the Extreme Programming methodology which is a popular agile approach [12]. Canning et al. [3] characterise the development process of the CLUE curriculum mapping tool as following a design-based approach. It involves stakeholders providing regular input on the way how the curriculum data were visualised and what functionality was added to the tool. The iterative development process had three main milestones: 1. functional prototype; 2. user interface prototype; 3. final iteration.

As was already emphasised in the section 4.12, usability evaluation phases and collecting user feedback are important steps that should not be omitted in the development of curriculum mapping software [2,4].

4.14 Are those recommendations acceptable not only for curricula in medical education?

It is interesting to consider whether recommendations from this report may be generalised into other than medical disciplines. Helpful in that was a study by Rawle et al. [57]. Based on a systematic literature review, but also on local discussions between several departments at the University of Toronto Mississauga including faculties of Biology, Geography or Language Sciences, the authors have shown significant common ground in requirements across the disciplines. This involved both the curriculum implementation process as well as visualisation methods. For instance, the Excel spreadsheets with coloured columns are often seen as an entry point into curriculum mapping which may be later expanded by more sophisticated presentations. There are developments in progress how to enable the faculties and students to run their own on-line queries regarding the curriculum content. It is a common challenge that pedagogic jargon makes it difficult for the faculties to get involved in curriculum mapping that is an important lesson for design of user interfaces. Even though not shared by all, the researchers saw the need at some faculties (even very distant from medicine as geography/environment) to use curriculum mapping to respond to national accreditation processes which implies also a use of common learning objectives catalogues as is common in medicine.

Ellaway at al. state that while MedBiquitous Curriculum Inventory Standard was developed for medical education and largely by those with a role in medical education, it should work in any health professional curriculum and, at least potentially, any other kind of curriculum [25].

Aldrich sees curriculum mapping as a vehicle for crossing borders between traditional academic disciplines. Modern, active fields of study are at the intersection of several disciplines (e.g. biomathematics, bioinformatics, medical informatics) and there is a need for initiatives that would integrate siloed curricula [20]. This function could be played by the BCIME project platform.

5. Discussion

In this intellectual output we present a compilation of the most recent recommendations regarding development of curriculum mapping software. Modern information systems are web-based, support a hierarchy of different user roles and give a comprehensive, interactive overview of the curriculum with various forms of presentations including coloured tables, networks, balloon charts and many others. It is crucial to equip a curriculum mapping tool with easy access to current competency frameworks relevant for the given institution. This includes support for national learning objectives catalogues, but may contain also institutional target outcomes or specialised competencies of selected medical fields. In many cases of here analysed systems those catalogues were arranged in a hierarchy of rising granularity and enabling different levels of analysis. Controlled vocabularies like the MeSH thesaurus facilitate intelligent free-text search functionality. The user interface of the IT system needs to be easy to use but powerful to support the stakeholders in coping with the effort of describing and analysing the curriculum. For that reason, it is important to complete usability tests and offer auto-completion of simple tasks. In order to be well-accepted a system needs to be customised for the particular needs of the target environment. At the same time, it is necessary to permit data export for reporting purposes in standard formats, e.g. as the MedBiquitous Curriculum Inventory. Also, a curriculum mapping tool has to be open for integration with other elements of the university information system including learning management systems (LMS), scheduling services or terminology servers.

A graphical overview of identified features of the curriculum mapping tool is presented in Fig. 9.

Fig. 9 A mind-map of features to consider while implementing a curriculum mapping system

The strength of our intellectual output report is a systematic approach to literature search which combined with both technical and medical expertise of project partners gives a comprehensive view on the state-of-the-art in developing computer-based curriculum innovation in medical and healthcare study fields. This report is structured with a list of the most important features to be developed in a curriculum mapping systems derived from a needs analysis which adds to the relevance of the recommendations. The importance of the report lies in delivering a toolkit of tested solutions reported in the literature or derived from local experiences that may be, depending on the institutional needs, be applied on selected steps in the development process.

The report is limited by a relatively narrow timespan including literature published in the last five years and by the focus on a single research database. However, this was planned from the beginning considering the allocated time resources of the project. It is also worth emphasising that among the included studies were systematic reviews [32,57] and studies based on scoping reviews [12] that included recommendations derived from a broader range of published studies. We also added manually five important papers identified by hand-search of the literature references.

Our review focused on those aspects that are directly related to the development of technical features in curriculum mapping software. The discussion of topics related to the management of human resources in curriculum innovation was excluded from our review. For instance Lammerding-Koeppel et al. underscores the need for adequately trained staff and establishing of effective communication structures including high-ranked members of the faculty as the basis for a successful curriculum mapping initiative [23]. It is important to not only to develop the new features of curriculum mapping, but also consider how to train staff for this process, how to facilitate communication and how a system could support these aspects.

Furthermore, we do not cover the methodology for development of curricula *per se* in this report. For instance Komenda et al. presents a four stage model for planning curriculum innovations in the context of use of the OPTIMED system [13]. Despite its importance, we regard this to be a very broad topic and largely independent of the applied technology and by that out of the scope of this report.

A point worth considering for which the literature does not give a clear answer is the required level of granularity of the mapped elements of the modelled curricula. The analysed studies show a high degree of heterogeneity regarding that aspect. Common in the studies are multi-level hierarchies showing a transition from high level gross descriptions to fine-grained detailed views of the curriculum. The elements presented in such hierarchies are mainly competencies: ranging from a few items at institutional level up to thousands of detailed objectives at single session levels. Different controlled vocabularies are presented at subsequent levels. Hierarchical structures describe also the organisation of teaching and assessment ranging for a few study blocks (disciplines) out of which the whole curriculum is composed to the level of individual items in multiple-choice tests. Fine-grained descriptions leverage a powerful search functionality and high quality reporting, but at the same time this generates a lot of effort in data entry and management that might easily go beyond the available time and personnel resources.

The unique aspect of our project is its internationalisation. Most of the systems in our review are nation-level solution - e.g. LOOOP and MERlin in Germany, CurrMIT in North America or Entrada in Canada. The solutions that the BCIME project is going to propose need to cross borders of several European countries each with individual requirements. Aspects as support for multiple competency frameworks, localisation of the user interface to several languages and deployment of the system for use in different higher education institutions is, for curriculum mapping software development, a process that requires pioneer work.

Even though the project partners of the BCIME are rooted in medical faculties, we have also a strong technical background. Our know-how grounded in experience and the analysis of the literature brings us to the conclusion that the lessons learned while working on the new features of the curriculum mapping tool have the potential, with some minor modifications, to be generalised to other than medicine and healthcare related disciplines.

6. Conclusions

The aim of this intellectual output was to compile a set of recommendations and good practices regarding the development of a software platform for curriculum innovation and mapping. A systematic search of literature published in the last five years, enriched with experiences of the five project partners, resulted in a comprehensive overview of what and how is nowadays implemented in curriculum mapping software. Structured by the key characteristics from the needs analysis reported in the first intellectual output (IO1), the recommendations form an easy to use, step-by-step toolkit to inform and inspire those working on establishing a new or extending the functionality of existing electronic curriculum mapping systems.

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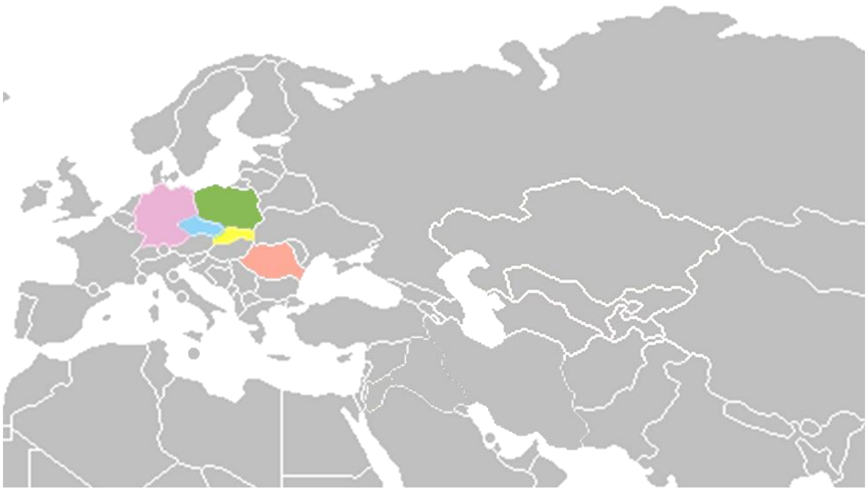
Appendix 1

Standardized form of course syllabus

COURSE INFORMATION LETTER

University:	
Faculty:	
Course ID:	**Course name:**
Course type, scope and the method: **Course type:** **Recommended course-load (hours):** **Per week:** **Per study period:** **Course method:**	
Number of ECTS credits:	
Recommended semester/trimester of the course:	
Course level:	
Prerequisities:	
Conditions for course completion:	
Learning outcomes:	
Brief outline of the course:	
Recommended literature:	
Course language:	
Notes:	
Course assessment	
Provides:	
Date of last modification:	
Approved:	

Page: 1



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