Reconciling Instructors' and Students' Course Overlap Perspectives via Linked Data Visualization

Fouad Zablith and Bijan Azad

Abstract*—Research on the use of modeling and mapping tools in curriculum management is thriving, often focusing on the perspectives of the faculty alone. However, scholarly works that also incorporate the students' curriculum concerns are rare. A recurring theme in students' curriculum concerns is the perceived overlap among courses, usually expressed at the level of common concepts across courses. This common "concept" emphasis imposes a challenge for modelers, who often focus on the course level comparisons because they usually lack tools with sub-course (concept) level granularity. This paper investigates how to model and represent curriculum information to help in reconciling the gap between instructors' and students' views of cross-course overlap. The proposed approach involves the design and development of a digital environment to 1) model a curriculum via linked data through an ontology representing concept-level granularity; 2) offer instructors aid in populating course content; and 3) facilitate the visualization and manipulation of data. The visualization tools are designed to offer functions for perceived common concept overlap identification and rectification. This digital environment was deployed and evaluated in the context of a curriculum review process, in which 25 course instructors employed the visualization tools to address a perceived course overlap problem. The preliminary results demonstrate, first, the usefulness of the approach in reconciling the views of instructors and students regarding perceived course overlap. Second, the results highlight that the approach contributes to transforming course overlap from a fuzzy notion to a more concrete and actionable construct defined as either *repetition* or *reinforcement*.

***Index Terms*—Course overlap, curriculum mapping, knowledge graphs, linked data, ontologies, semantic web, visualization.**

I. Introduction

In the last two decades, the influence of accrediting bodies as well as competition among programs and schools have forced universities to institute more systematic approaches to whole curriculum design, management, and transformation (e.g., [1]). Simultaneously, the traditional curriculum management approach of focusing on syllabi, course catalogs, and the list of course sequences/prerequisites has increasingly given way to curriculum mapping and modeling studies (e.g., [2]). More specifically, a problem area that is starting to attract the deployment of visualization tools in combination with curriculum mapping and modeling involves ensuring that university degree plans contain the least amount of "overlap" possible across courses to increase efficiency (e.g., [3]). However, capturing potentially different stakeholder perspectives on course overlap—e.g., those of instructors and students—has remained secondary within this research.

As such, designing, deploying, and evaluating a novel integrated configuration of modeling, mapping, and visualization components under one roof in order to analyze course overlap from the perspectives of instructors and students can both help advance our understanding of the overlap problem and provide us with a repertoire of curriculum modeling tools. Students often focus on perceived overlap among courses, stating, for example, "but we studied five forces of strategy in marketing too!" or "five forces were covered in management!" Perceived overlap requires zeroing in on common phrases (e.g., concepts) as basic elements of commonality among courses. However, instructors often rely on course-level representations to navigate and explore the substance of overlap because traditionally there is a dearth of curriculum management tools and models at the (sub-course) level of concepts. This creates a gap between what students consider as overlap, and the curriculum administrators' ability to respond to such feedback. Furthermore, as one starts to focus on the notion of "overlap" among courses, a host of definitional, granularity, and ontological as well as practical issues take on urgency. For example, one might ask such questions as, "How should the difference between perceived and substantial overlap be incorporated in modeling environments?" "How should the overlap be represented?" "How should it be displayed?" "What should be done to enable finding it," and "What should be done once the overlaps are found?" Our paper aims to contribute to this literature. Therefore, we propose to investigate the following research question: *How should we model, represent, and visualize curriculum information to enable us to reconcile perceived versus substantial overlap, so that we can detect and rectify the latter?*

In this exploratory study, the objective is to investigate how linked data, coupled with appropriate visualization tools, can help in identifying course overlap and reconciling the perception of overlap versus its substantial existence. To operationalize this objective, we design and develop a digital integrated framework to 1) model curriculum-linked data following an ontology to represent curriculum courses, topics, and relations down to the level of concepts; 2) populate data to capture, store, and publish curriculum-linked data; and 3) manipulate and visualize the data through a set of four differ-

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ent visualizations that provide a variety of features to represent overlap at the sub-course granularity levels. We then perform a preliminary evaluation of the proposed approach via an international accreditation-based initiative, in which 25 faculty members participate in the overlap detection and rectification task as part of the curriculum review of an AACSB-accredited business school. The initial results highlight the utility of the proposed curriculum model design as well as the associated digital environment in supporting the process of course overlap detection and rectification. We believe there are many lessons to be learned from our attempt at reconciling the instructor and student perspectives.

Our study contributes to the extant research on curriculum modeling, mapping, and visualization in two ways. First, we propose a modeling environment that can capture and integrate instructor and student perspectives on course overlap more comprehensively, efficiently, and effectively. Second, our empirical analysis led us to construct a general scheme whereby course overlap can be either classified as knowledge *repetition* or as knowledge *reinforcement*.

The remaining parts of the paper are structured as follows. Section II presents the background and related work in the field. Section III discusses the research methodology, followed by the evaluation of the approach presented in Section IV. Section V concludes the paper with a discussion of the contributions, research limitations, and future research directions.

II. Background and Related Work

A. Managing Curricula via Course Modeling and Mapping

The analysis of educational programs often involves exploring alternatives and pinpointing observations, and subsequently introducing a curricular change or reform [4]. When curricula are subject to change, educational organizations too often face the significant challenges of the so-called “needle in a haystack syndrome” [5]. Many factors contribute to this problem, including for instance 1) the fact that curricula knowledge are often black-boxed and spread across various sources in the organization (e.g., course syllabi and catalogs); and 2) the lack of appropriate tools to capture and represent sub-course curriculum content, for example at the level of concepts, to enable more granular information for decisions fit for the task at hand. Tackling such challenges can be a boon to educational organizations’ efforts to provide students with a better learning environment. In fact, the effective and efficient management of perceived course overlap is seen as a core strategy of universities to improve students’ education experience [6].

Indeed, we are witnessing increased research interest in supporting solutions for a variety of problems in curriculum analysis. For example, Gluga *et al.* [2] focus on modeling university curricula by mapping courses’ learning objectives. They propose a “lightweight” curriculum mapping approach to align the learning goals supported by multiple internal and external accreditation bodies. Their method involves an ontology that maps the different curriculum elements concerning learning goals, which are used to develop a digital platform to analyze courses with respect to the related learning objectives. Other efforts have focused on investigating techniques for visualizing curriculum content [3], [7]. Siirtola *et al.* [3] investigate an approach for visualizing curriculum content and the associated overlap. They propose a visual tool that can support the identification of overlap instances across degree programs among faculties. However, they highlight the labor-intensive nature of the work required to bring lecturers together for mapping the overlapping topics in the curriculum. One of the challenges they face is how to align the different instructors’ approaches in mapping curriculum topics at the appropriate and relevant abstraction and granularity levels. We see an opportunity to extend these lines of work by providing an integrated web-based environment to model, collaboratively create, and visualize curriculum data to afford the appropriate level of granularity.

B. Linked Data in the Education Domain

The web is increasingly seen as a platform to deliver personalized tools and applications that are adaptive and accommodate evolving user needs [8]. Numerous applications have been studied in different contexts including education, leading to the development of adaptive educational hypermedia in online learning environments [9]–[11]. Since the inception of the Semantic Web vision [12] and linked data [13], content published on the web has increasingly incorporated entities with explicit and machine-processable semantics. Linked data relies on using ontologies and common vocabularies to make it possible to establish links at the data level—rather than at the document level—on the scale of the World Wide Web. Such semantically rich and linked data are opening up opportunities to create web-based applications that are an order of magnitude smarter and more sophisticated. Anderson and Whitelock [14] concur with this view and propose a vision of an “Educational Semantic Web.” Indeed, the Semantic Web and linked data have increasingly played a more significant role in supporting learning technologies [15]–[17]. Certain challenges, however, constrain the expansion of the latter. For example, agreement on using unified ontologies to represent the educational domain is lacking [18]. Furthermore, it is argued that for such technologies to reach greater maturity and take-up, a deeper understanding is required of how specific user types (e.g., instructors in the educational domain) put such technologies into practice [19]. Specifically, understanding the potential of semantic technologies and the mechanics of their applications in assisting educational administration tasks (e.g., curriculum review and management focused on reconciling instructors’ and students’ views) remains an under-explored area of research.

It is important to acknowledge the progress made so far in the domain of education. For example, common standards and vocabularies are proposed to better connect educational platforms [18]. However, research has also highlighted the heterogeneity that exists in published educational datasets [20], [21], to the extent that high-level services are needed to keep track of existing and newly emerging datasets and to increase the possibility of interlinking and reusing published data [22]. Furthermore, the major rise in the availability of online courses and Massive Open Online Courses (MOOCs) on various platforms is increasingly seen to benefit from the use of linked data [23]. Indeed, there are several examples of successful educational applications in which videos and online materials [21], [24]–[26], research publications [27], [28], books, and scholarly articles [29] generated or adopted by various educational organizations have been successfully connected and linked.

Interestingly, the growing pool of datasets, as well as the associated linkages and tools, indicate that the lion's share of existing linked data approaches in educational contexts are focused on interlinking high-level resources and data. The available vocabularies reflect this fact, as indicated by the major vocabulary catalogs (e.g., Linked Open Vocabularies (LOV) [22] and Linked Education [30]). Examples in this context include the Academic Institution Internal Structure Ontology (AIISO) [31] and the Courseware ontology [32]. These vocabularies largely represent university-level curricula and at best may go down as far as course-level representations. Therefore, we observe that linkages represented by these vocabularies do not capture information deeper than the subject and high-level content coverage of the courses. This situation constrains the types of tasks that can be performed, especially curriculum management tasks that may require more granular curriculum information that students can relate to (e.g., concepts in the context of cross-course overlap).

Others, for example Poore [33], have identified several teaching and learning tasks that can be supported by Semantic Web technologies—e.g., seeking out educational content, planning courses, and deciding upon curricula. However, so far there appear to be few scholarly works that attempt to put such technologies in the service of practical curriculum review and analysis—e.g., tackling students' views of course overlap, which requires the ability to capture data at a more granular level than the existing Semantic Web and linked data vocabularies. Our work aims to address this literature gap in two ways. First, we propose a distinctive curriculum model that involves designing an ontology that builds on the available existing ontologies described above to model and map curriculum-linked data at the sub-course level of granularity. Second, we have designed, developed, and evaluated a digital environment that integrates the modeled linked data with visualization tools, supporting administrators and instructors in overlap detection and rectification tasks while incorporating students' views of course overlap.

III. Research Methodology

A. Conceptualizing Course Overlap

Our research objective is to design, develop, deploy, and study a digitally enabled environment that allows administrators and instructors to examine issues of concern within a university faculty curriculum management context. The focal issue is to study and reflect on how designing and using such an environment could help in reconciling different instructor and student perspectives about overlap among courses within an undergraduate business curriculum. The inception of this project is traced back to a town hall meeting related to the reaccreditation of the Business School when some students complained about the repetition and redundancy in the curriculum. There were subsequent discussions with faculty members who are engaged in curriculum review and design matters in the Business School. These discussions eventually led to a formal initiative that focused on how the perceived course overlaps reported by students can be rectified.

These discussions revealed a repetitive process in the way faculty tackled the overlap issue. First, faculty largely relied on their syllabus, started browsing the topics mentioned in it, and drilled down in their books to see what is covered in certain topics. Then they looked up other courses' content through course catalogs. Second, faculty started analyzing whether certain perceived overlaps were valuable to have, or perhaps with clarifications for to students about the presence and desirability of these overlaps. In some discussions, though, we saw faculty defending the students' position and supporting their complaints. In other words, the faculty appeared to be equally open to classifying overlaps according to their own understanding or students' views. Third, faculty appeared to move toward exploring concrete means of resolving the overlap in their courses. In summary, the alignment of the students' perceived view of overlaps with the instructors' substantial view of overlaps emerged as a three-step process: identify the perceived overlap, classify the perceived overlap, and rectify the perceived overlap.

It is important to underscore that the existing course representations via syllabi, catalogs, and textbooks provided little consistency across the curriculum. On the one hand, during our discussions, faculty emphasized that overlap can be thought of at the level of course subjects, for example between an "information systems" course and a "management" course, given that they both cover the topic of "organizational strategy." On the other hand, an overlap between these two courses can occur, for example, at the conceptual level of "five forces of strategy," which refers to notions at the sub-strategy level. The latter view of overlap is closer to the students' conception, that is, it is close to perceived overlap. Hence, we converged on a relational conceptualization of perceived overlap as understood by students, as the occurrence of commonly labeled concepts across courses.

To summarize, our discussions with the faculty as well as our own analysis of the information base needed for solving the course overlap problem culminated in recognizing two key shortcomings that needed to be addressed. First, the content of courses lacked a unified and hierarchical schema, or any central repository, which made it extremely difficult to detect potential overlap across several courses. Second, without properly designed tools with the appropriate level of sub-course granularity, there is inadequate visibility of overlap manifestations for faculty members to detect, classify, and rectify overlap as perceived by students. Next, we turn our attention to describing the development of models and tools to tackle these gaps.

B. Developing a Course Overlap Analysis Information Base

To enable instructors to analyze the course overlap situation, it would be helpful to develop a modeling environment that provides sub-course level information features to detect, classify, and rectify perceived overlap. Toward that end, we propose an integrated environment that provides the following components and associated functions as depicted in Fig. 1: 1) a component that provides curriculum linked data modeling functionalities through an ontology that can represent common information among courses, topics, and corresponding concepts—the whole representing perceived overlap; 2) a component that offers capabilities to collaboratively populate the curriculum model with relevant data via capturing, storing, and publishing course content data using a Semantic MediaWiki; and 3) a component that provides visualization and manipulation features for curriculum content to enable perceived overlap detection and rectification at relevant granularity levels—namely, common concepts and related topics across courses.

1) Modeling curriculum-linked data using an ontology: We discuss in this part how our proposed ontology can help model and represent curriculum entities and relations that are a core requirement for linking courses with common concepts. The ontology enables user control over the creation of the linked data entities. Also, because the ontology follows a well-defined structure, it facilitates the reuse and streamlined processing of curriculum data. Every node defined in the ontology will have an explicit type (e.g., course) with semantic relations to other entities (e.g., a course related to a certain topic). Consistent with the state-of-the-art principles of linked data [13], we employ existing ontologies to enable an easier exchange of data with external entities. Based on relevance and fit for our application, we reuse, combine, and extend entities from existing ontologies, namely Courseware [32] and AIISO [31]. These were identified via the main vocabulary catalog providers [22] and online aggregators of linked data in the educational contexts (e.g., the Linked Education website [30]).

Fig. 2 presents the proposed ontology and its associated context with the reused ontologies. A "course" entity (reused from AIISO) has a "code" (also reused from AIISO), and a certain "number of credits" (reused from Courseware). It is "taught at" (reused from Courseware) a certain "organization" (reused from AIISO), "has prerequisite" (defined by our ontology using our wiki namespace), "has subject" (defined by our ontology using our wiki namespace), and "covers topic" (defined by our ontology using our wiki namespace). The topic entities "include" "learning concepts" (defined by our ontology using our wiki namespace). For example, a course on the "foundations of information systems" can be part of the "information systems" subject, and covers different topics such as "database processing," "business intelligence," and others. Each topic usually covers more granular "concepts" such as "structured query languages" that are part of the "database processing" topic.

The nodes that are directly connected to the "course" entity in the core of the model are identified from the courses' syllabus structure that is traditionally used to describe courses at the Business School. For example, "topic", "credit hours," and "subject" are explicitly defined in syllabus documents and can be easily combined to perform high-level course comparison and analysis. In addition, a key objective of this research is to offer the ability to identify and analyze perceived overlap among courses within the curriculum at different granularity levels that are consistent with students' views of overlap. This will allow perceived course overlap to be assessed and rectified by instructors. Such analysis would require fine-grain information that goes beyond syllabus information (e.g., what is taught within each topic), and is thus more complex. Capturing sub-course information via concepts is a key ontology design feature, which can enable us to implicitly and indirectly model overlap through the common concepts in courses.

Another added value of such ontology is the ability to standardize the connections among courses in the curriculum in a coherent way at the sub-course level. Furthermore, the ontology helps in de-black-boxing the common cross-course connections that were formerly latent. For example, it is possible now to perform information comparison across courses quickly and to consider analyzing concepts covered according to their topics within a course, or according to their course within a subject, or according to their subject within a faculty (i.e., organization). Our ontology allows for enhanced customization and ease of use in tackling a complex hierarchy of courses, topics, and concepts.

2) Populating curriculum data: capturing, storing, and publishing linked data using a Semantic MediaWiki: We deployed a Semantic MediaWiki to collaboratively capture, store, and publish the curriculum-linked data. We involved faculty and teaching assistants to capture the data using the MediaWiki. The wiki is part of a larger project that aims to link university data. The platform is accessible online and is available for anyone to access and to contribute to [34]. One of the features of the Semantic MediaWiki that played a major role in deciding to use this wiki is the presence of "forms." Such forms serve as a control mechanism to populate and extend the curriculum data following the proposed ontology. We hardwired our ontology with the wiki forms, which we designed to populate and interlink the various elements, such as courses, topics, learning goals, teaching materials, and concepts. The linking is performed by controlling the input boxes and by explicitly specifying the type of entity expected to be entered following the ontology (e.g., course, concept, and others). Subsequently, the interface would automatically provide relevant entities that are already present in the wiki, so that the user could reuse such entities and create the links. The latter step rendered perceived overlap manipulable and visible to instructors. Another important feature was the presence of unique resource identifiers (URIs). These URIs are one of the fundamental features of linked data and were crucial in enabling the creation of semantic linkages among entities in the curriculum—this was a core prerequisite for enabling the representation of overlap as common concepts across the course level.

The curriculum entities were generated based on a two-step process. First, principal investigators and teaching assistants (TAs) manually examined all the course syllabi and created a high-level representation of courses including the covered topics, course description, prerequisites, etc. In the second step, additional information on concepts was identified

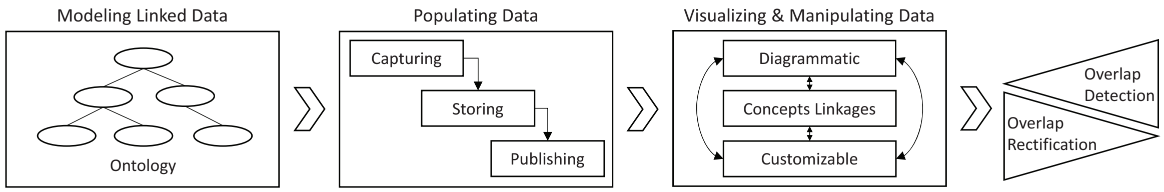

Fig. 1. Modules of the digital curriculum mapping and visualization environment.

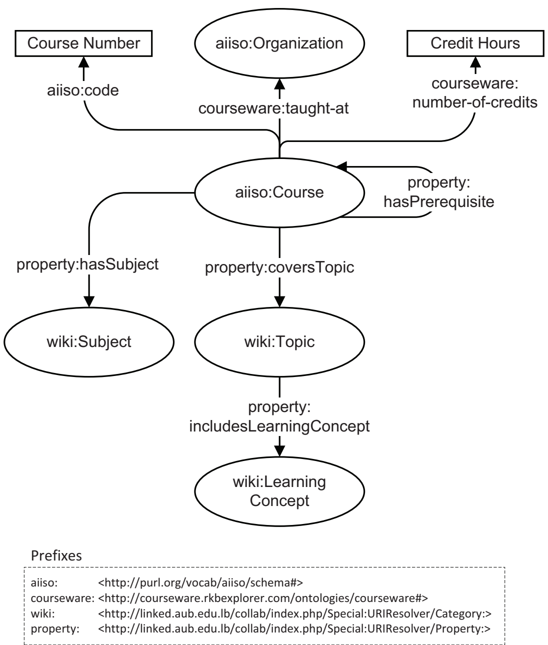

Fig. 2. Ontology to model curriculum linked data and conceptual connections.

from textbook materials. Following a "knowledge factory" process [35], we trained course TAs, who identified, extracted, and encoded concepts from the books. Concepts were defined as self-contained "labels" that are covered in textbooks within the topics defined in syllabi. For example, in a marketing course syllabus, the pricing strategies topic is related to the fixed and variable costs concepts in the textbook. Lecture presentations and handouts were also used as a guide to highlight the existence of common concepts among courses. TAs were instructed to identify and select the key concepts within the topics and enter them into our system via the wiki interface. TAs were also guided to reuse concepts that are automatically "proposed" to them through the wiki interface if they semantically match with the concepts of the course in the information base.

The consistency of identified and selected concepts among the different TAs was managed as follows. Initially, TAs entered the course concepts, aided by the automatic matching feature in the wiki. Subsequently, the principal investigators of the project and certain instructors did a quality assurance / quality control check of these data for consistency, and if needed, introduced any corrections, which were minimal.

In addition to capturing curriculum-linked data, the wiki was used as a platform for *storing* the modeled data. Given that the high performance and complex query features of full-fledged SPARQL were a low priority in our context, we relied on the wiki as the main repository for storing the linked data. In the future, if more features and querying capabilities are required, the data can be easily extracted and stored in native graph-based triple-stores to improve query performance.

Going beyond the storage of linked data, the wiki was used to *publish* the data for reuse in external application development. We relied on the wiki's semantic search features to access and extract the stored data (in JavaScript Object Notation (JSON) format) following the designed ontology [36].

3) Visualizing and manipulating curriculum data: Having captured the curriculum entities and relations as linked data, our next objective was to devise a means for faculty to explore the data to detect and rectify perceived overlaps. For this purpose, we leveraged the collected linked data to create visualizations that we refer to as linked data visualizations. The linked data triples (viz., subject–predicate–object) with the explicit semantics that follow the designed ontology offered flexibility to traverse the data and selectively visualize specific data elements. We accessed the linked data following the JSON format to generate different visualization tools. The proposed visualizations were designed to provide improved visibility of the curriculum-linked data to help in depicting perceived overlap via common concepts across courses.

Based on the feedback from the School's curriculum committee members who are involved in curriculum review and design tasks, a consensus emerged that faculty would have different expectations of the curriculum visualization tools. While some preferred more sophisticated visualization features, others opted for simple capabilities. Another requirement emerged from the discussions with the members. That is, to have a successful curriculum review and redesign, they wanted features that helped not only in exploring and identifying overlap occurrences but also in deciding what to do with such occurrences. Subsequently, we evaluated the existing online visualization packages as falling short of the needed requirements, since they provided inadequate support for visualizing the common concepts across courses in the curriculum. Eventually, based on a detailed review of "linked data visualization" [37] as well as "data visualization" (e.g., [38]) capabilities, we identified three key functionalities that needed to be provided via custom-designed curriculum mapping tools. First, the tools need to represent curriculum entities using *diagrammatic* features (e.g., using colors to draw the user's attention to important elements of the curriculum). Second, the tools should be able to depict complex curriculum connections via different *concept linkage* features (e.g., common concepts and links among courses should be made visible).

Third, the tools need to provide users with some degree of *customizability* to perform tasks with minimum effort (e.g., changing the selection of courses to display on the curriculum map).

One of the challenges we faced was how the custom-designed tools can cater to these different requirements "under one roof." We started by developing a visualization that rendered visible on one screen all concepts and courses and their corresponding "links." When we shared this visualization that we dubbed Forced-Node with some committee members, some members were pleased with it, while others found it overwhelming, as it did not display a clear hierarchy of courses and concepts among the data levels. Some described it as a constantly moving "jellyfish" that is hard to follow and difficult to make sense of. Subsequently, we created an additional visualization that we called Sankey, to enable instructors to select and focus on a certain course, render it visible on the screen, and gradually unfold the concepts related to this course. Upon sharing the Sankey visualization with the committee members, again some welcomed it, while others expressed some concern about the complexity of tracing the links on the screen in a meaningful manner. Certain members asked us to display the content in a traditional tabular format that can be used as a "simple map." Therefore, we developed a third visualization that we called a Mapping Table, which shows where each concept occurred in the corresponding topics and courses. This visualization displays all courses, topics, and concepts in one table. Then, further feedback from the committee members highlighted the need for a course-level view of how the different subjects within the curriculum compare. This motivated us to create a Treemap view of the curriculum. Via the Treemap view, users can navigate the curriculum at three different levels, starting by comparing the number of concepts covered at the subject level, and proceeding down to the course level and then the topic level. After sharing these four visualizations with the committee members and asking them to choose the appropriate one for the course overlap analysis, they could not agree on a single tool. After some intense debate, we decided to keep all four visualizations as part of this study to avoid straitjacketing members into using one tool, as this could negatively impact the use of visualizations. The full list of visualizations that we created as part of the project for dealing with overlap and other curriculum review tasks can be tracked on the curriculum data visualization page [39]. Table I provides an overview of the features provided by our four visualization tools. We describe each of the four visualizations in more detail next.

TABLE I
SUMMARY OF THE LINKED DATA VISUALIZATION FEATURES

Features	Forced Node	Sankey	Treemap	Mapping Table
Diagrammatic				
Explicit Connections	✓	✓		✓
Color Coding	✓	✓	✓	✓
Size Coding	✓	✓	✓	
Concept Linkages				
Curriculum Overview	✓		✓	✓
Shared Concepts	✓	✓		✓
Path Navigation	✓	✓	✓	✓
Customizability				
Focused View	✓	✓	✓	
Adaptive Screen	✓	✓	✓	✓
Filtering	✓	✓	✓	

Forced-Node graph visualization. The Forced-Node graph shown in Fig. 3, is a visualization that displays concepts and courses as nodes with links. At a diagrammatic level, the concepts in this visualization are connected to their courses in a node–link–node visual form. The links between the concepts and courses are created by inference through the topics—i.e., concept–topic–course relations. Colors are employed to highlight the selected nodes and provide a visual reference for the user (e.g., in Fig. 3 on the left, three nodes turned red after being selected by the user). Furthermore, the greater size of nodes reveals the higher importance of an entity in the curriculum based on its larger number of connections (commonality). Concerning linkages among concepts, this visualization gives an overview of the whole curriculum with explicit linkages. There is also the possibility of selecting specific courses for a focused exploration (e.g., Fig. 3 focuses on visualizing the perceived overlap in common concepts between a pair of accounting and finance courses). Fig. 3 on the right shows specific nodes selected from the larger graphic on the left, highlighting for example that "dividends" appears as a common concept (perceived overlap) between the accounting and finance courses. The visualization provides additional customization features, such as the ability to focus on specific nodes' connections by clicking on them. The Forced-Node visualization is built using the D3 visualization toolkit [40]. Our choice of this JavaScript-based toolkit stems from its high degree of customizability and interactive features. This enabled us to accommodate the "whole" curriculum data on one screen, combined with the possibility to adapt to users' distinctive need to drill down and narrow in on specific concepts.

Sankey visualization. The Sankey visualization, shown in Fig. 4, highlights the concepts a selected course has in common with the other courses in the curriculum. Sankey-style visuals are typically employed in industrial contexts [41]. We saw a potential value in adapting the Sankey to our context as a means of revealing perceived overlap—i.e., the existence of common concepts and topics across various courses in the curriculum. At a diagrammatic level, like the Forced-Node visualization, the Sankey visualization provides explicit linkages among the courses, topics, and concepts that are represented as nodes. In this visualization, the thicker the line connecting courses to other entities, the higher the number of common concepts. Fig. 4 is an the example in which a marketing course (the left part of Fig. 4) connects to 11 other courses in the curriculum (right part of Fig. 4). The nodes in the middle of Fig. 4 reflect the concepts that connect with the topics to their left and right. The "height" of a colored "vertical node" reflects high common concepts that involve linkages passing through this node. For example, Fig. 4 highlights the fact that the topic "managing marketing information to gain customer insights" covered in the marketing course has a large

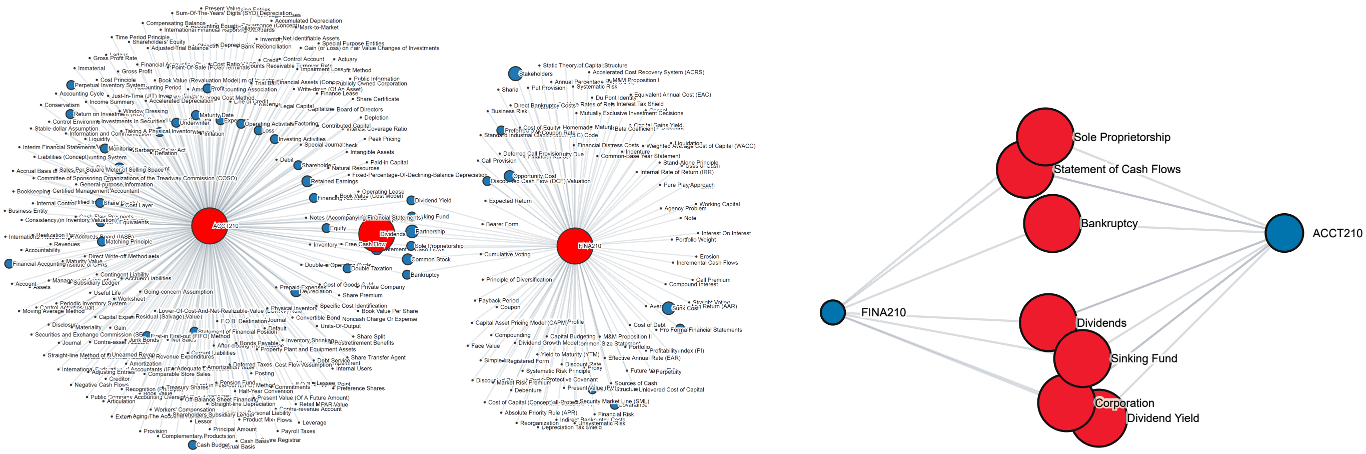

Fig. 3. Forced-Node visualization of the finance and accounting courses' concepts expanded on the left, and a selection of shared concepts on the right.

number of concepts (e.g., secondary and primary data) in common with other business courses in the curriculum. Entities with different colors are used to show the contrasts between the courses and concepts, as well as the links connecting them. The Sankey visualization displays common concepts and associated topics across courses as links. Such linkages can help with highlighting course, topic, and concept sequences and interdependence among courses in the curriculum. The interface provides users with the functionality to select a specific course in part (a) of Fig. 4. The technical process of using the Sankey is as follows. After clicking on the "submit" button, the tool first provides text-based information in part (b) of the screen, which reveals the total number of concepts covered in the course with the number of concepts it has in common with other courses in the curriculum (part (b) of Fig. 4). Then the related entities of the selected course are extracted and visualized via the Google Charts API [42]. The selected course is visualized in part (c) of Fig. 4, followed by its topics in part (d) that cover the shared common concepts in part (e) with the other courses in the curriculum. The user can trace if these common concepts exist among other topics in part (f), and finally, the other related courses are shown in part (g). The user is also able to "hover" on the links to get further information on the source and destination of a connecting link among entities.

Treemap visualization. The Treemap visualization, shown in Fig. 5, enables an incremental exploration of information covered in the curriculum. At a diagrammatic level, the Treemap visualizes the subjects, courses, and topics as nodes. The links are vertically traversed from the root of the tree (i.e., subjects), down to the tree leaves (i.e., topics). In this visualization, the size and color of the nodes are rendered based on the number of concepts that exist at each level. The concept linkages and subjects (e.g., accounting, marketing, etc.) are first displayed at the macro level. Once a subject is selected, the courses belonging to the corresponding subject are revealed. Then, when a course is selected, its associated topics are displayed. Subsequently, the number of concepts can be displayed by hovering on a topic. Furthermore, the user has the ability to drill down to the source page wiki of a specific topic. Via this visualization, curriculum links can be traversed through hierarchical connections between the nodes, with the ability to ascertain the source of concepts (i.e., back to the wiki). While traversing the tree, the categories are displayed in gray (e.g. the "business" subject and related courses in Fig. 5), and the related nodes are displayed below each category. The screen interface of the Treemap is adaptive and can automatically adjust to the content selected by the user (e.g., the node colors and sizes that are generated based on the curriculum data associated with the nodes). This visualization is also developed using the Google Charts API.

Mapping Table. The Mapping Table, part of which is shown in Fig. 6, visualizes in a tabular format the list of courses, their corresponding topics, and the covered concepts. Diagrammatically, the cells in the first row and the column headings represent the nodes, while the links in this tabular representation are denoted by an "X" mark. Colors are used to differentiate the different node types; for example, courses (depicted in the top row of Fig. 6) are colored in gray, topics are in yellow, and cells that contain common concepts are colored in red. Also, similar cases are depicted through multiple occurrences of "Xs" in the corresponding cell to show the number of times a concept is common among two topics (e.g., Fig. 6 shows that the "cash budget" concept is covered under two topics in two different accounting courses). Also, the origin of the concepts can be traced by looking up concept descriptions contained in the Semantic MediaWiki. Effectively, the Mapping Table provides a macro view of the courses as a whole within the curriculum, and at the same time, it affords the ability to zoom in at the level of course concepts. This visualization provides distinctive user customization features. For example, animated pop-up windows appear when users hover over the cells with common concepts. This would be an indication of the presence of perceived overlap. The Mapping Table is created by enclosing and importing the related course data in an HTML table and jQuery [43] elements.

IV. Evaluation and Results

In order to assess the potential impact of our approach, we collected the feedback of faculty members at the School

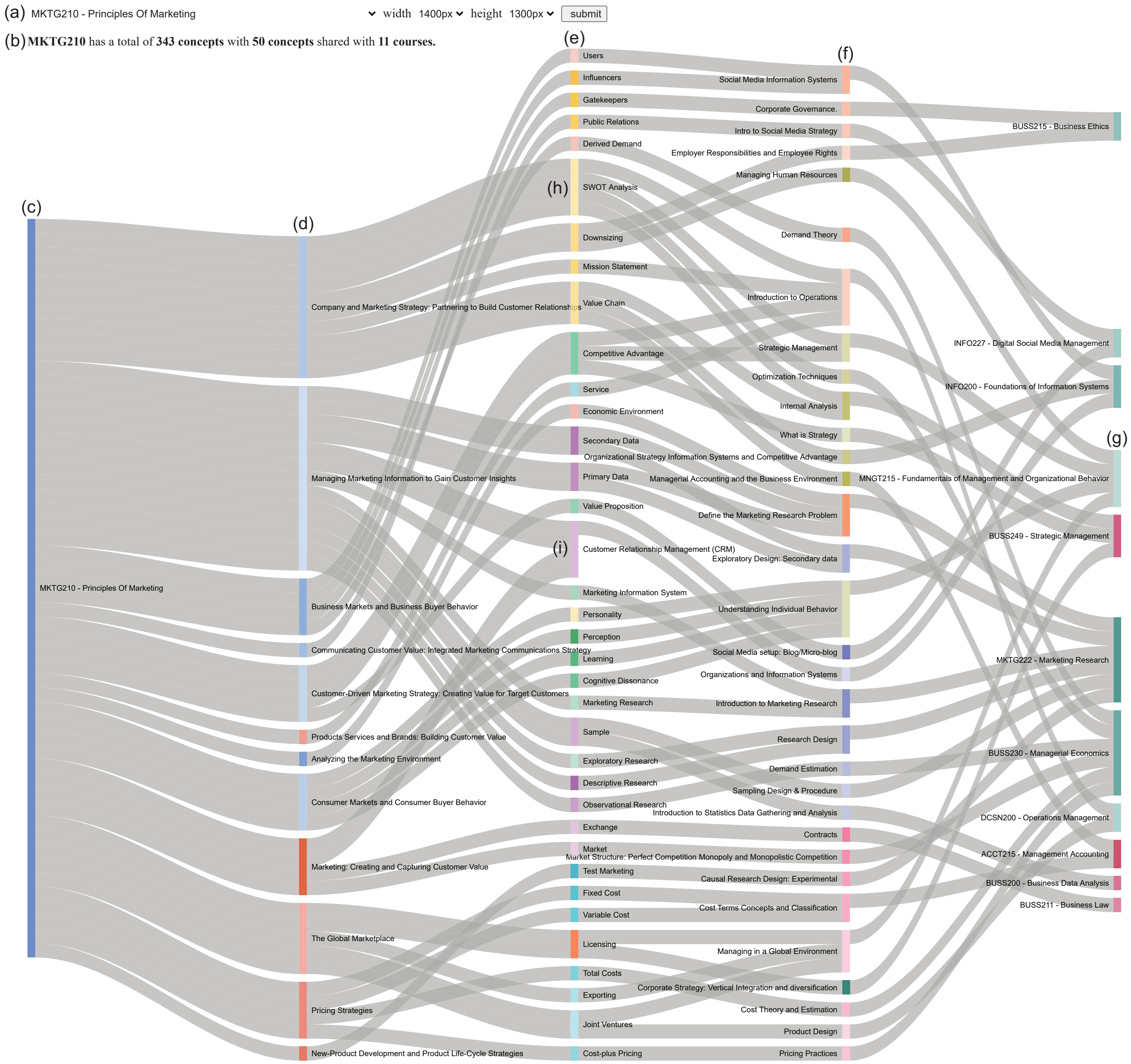

Fig. 4. Sankey visualization showing linkages between a marketing course and the other courses in the curriculum.

of Business of one of the leading universities in the Eastern Mediterranean. As part of its accreditation process, the School formally reviews its curriculum periodically. We took advantage of one of the School's once-every-five-years curriculum review exercises to evaluate the instructors' use of the curriculum visualization and manipulation digital environment.

One key objective of the curriculum review of the Business School was to reduce overlap among courses in the curriculum. The motivation for this goal emanated from several students' expressed concerns about similarities among different courses in the Business School curriculum. In line with our research objective, and in close cooperation with the School's Curriculum Committee, an initiative was formulated for the instructors to investigate the potential overlap between their own courses and other courses in the curriculum. Twenty-five full-time faculty members who teach core courses volunteered to employ the visualization tools to detect and potentially rectify perceived course overlap. Most of the faculty members have more than seven years of experience in teaching.

Instructors were given the opportunity to explore perceived course overlap, using the tools we provided to analyze the content of their courses. They were encouraged to think aloud during the session and be as explicit as possible when using the tools. At the end of each session, we interviewed the participants and asked them a set of open-ended questions to assess their views on the four visualizations. We used the following semi-structured, open-ended questions to elicit the participants' detailed views on several aspects of the

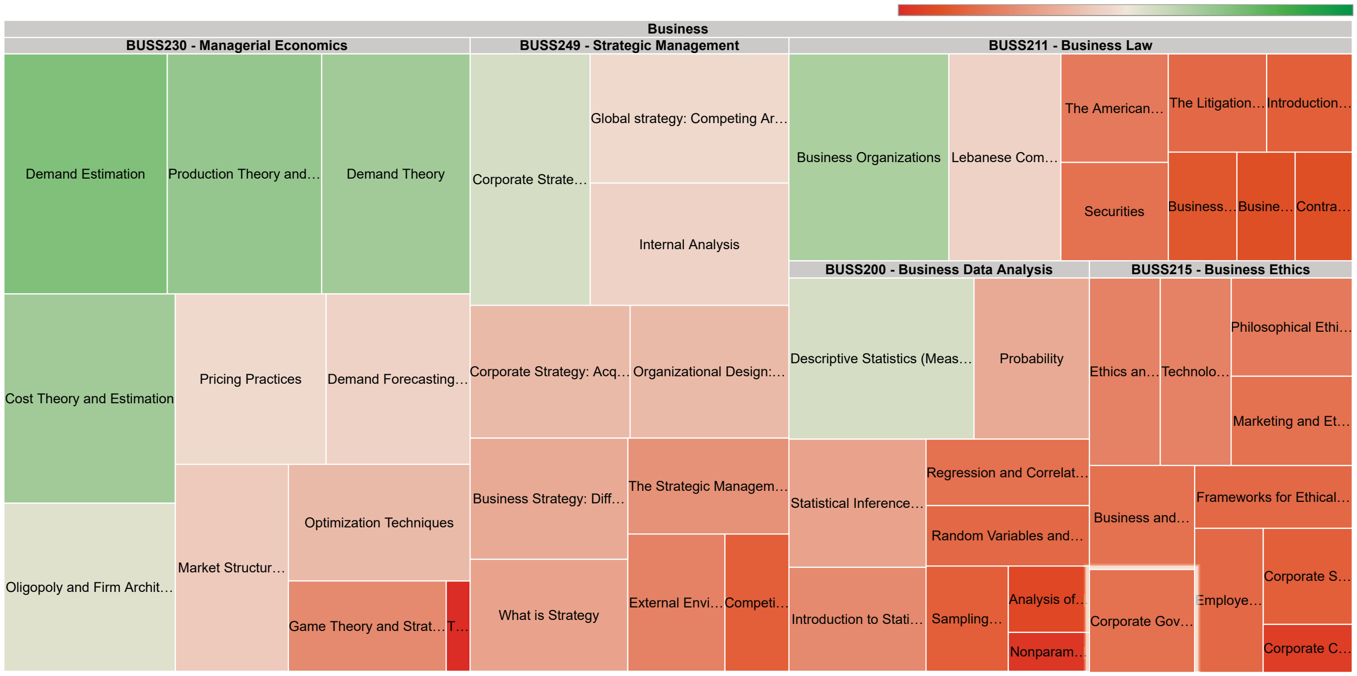

Fig. 5. Treemap visualization.

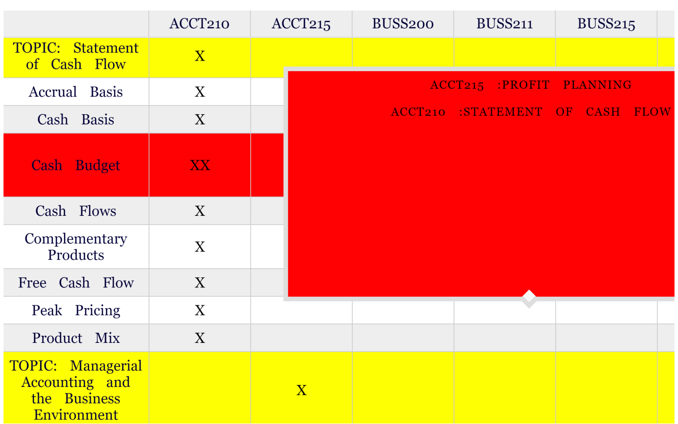

Fig. 6. Mapping Table.

curriculum review process enabled by the digital environment:

- Which visualization did you find the most (and least) useful? Why did you find it the most (least) useful? Can you elaborate on the how/process?
- What kinds of things did you come across or discover that you had not expected (new discoveries/things you were not aware of in your course/curriculum)? Can you elaborate on the how/process?
- Do you have any suggestions for improving the visualizations?
- Do you have any suggestions for thinking and doing the curriculum review process as a result of today's work with the visualizations?
- Would you like to add any further comments?

With the Institutional Review Board's approval and the participants' consent, the sessions during which the participants worked on the task using the curriculum mapping tools were recorded and transcribed for further analysis. In this section, we summarize 1) the data generated from the curriculum mapping step; 2) a use case on how the tools were employed in the course overlap identification and rectification process; and 3) the initial reflections and outcome of handling perceived course overlap.

A. Data Generated from the Business School Curriculum Mapping Effort

As mentioned earlier, we used in this study a Semantic MediaWiki, which is based on the linked data graph model, to capture the concepts and their connections in the School of Business curriculum. Project investigators, faculty, and teaching assistants collaboratively worked on creating and populating the curriculum data. We captured in the digital environment 20 courses in seven subjects, which cover 170 topics, aggregating more than 2500 concepts—effective and efficient handling of these concepts is a key feature of our designed environment. The number of concepts mapped in each of the seven subjects is shown in Fig. 7.

Performing an initial review of the common concept–topic links in the data reveals that approximately 20% of concepts (i.e., 500 out of 2500 concepts) are common to more than one topic in the curriculum. Thus, we may surmise that, as a preliminary estimate, the total proportion of potential cases of perceived course overlap is approximately 20%. However, determining whether these instances of perceived overlap actually constitute cases of substantial course overlap necessitates an exploratory analysis via the visualizations by the instructors. The process through which the instructors employed the digital environment to explore the existence and resolution of substantial course overlap is described next.

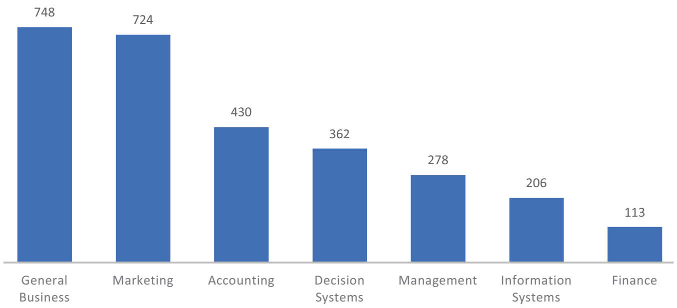

Fig. 7. The number of concepts modeled per subject in the Business School curriculum.

B. Use Case for Enabling Course Overlap Handling via Linked Data Visualization Tools

1) Course overlap handling process: identifying-classifying-rectifying: The use case was designed to dovetail with the high-level scheme described earlier. Each participant was given a task related to one of the courses she/he is teaching. The objective of the task is to investigate perceived overlap and determine whether there is a substantial course overlap to be rectified. Although users had equal access to course syllabi, textbooks, and digital visualization tools, most of the participants relied more heavily on the latter to address the task on hand. An implicit conclusion could be drawn that the digital visual tools enabled them to better interact with the curriculum content—however, testing this finding formally was beyond the scope of our research. The participants appeared more or less to follow a three-step process as described earlier: identifying a perceived overlap, classifying the overlap, and rectifying the overlap.

Identifying a perceived overlap. After listening to the problem statement related to students' concern with perceived overlap, instructors started investigating the potential existence of a substantial overlap between their courses and others. First, most of them started exploring the different available tools. They compared the different visualizations' features. Second, they often spent a short period of time on each of the four tools to individually manipulate the features provided. They zoomed in on the content of their course and contrasted it with the content of the other courses. They were going from a course-level view to a topic comparison, zooming into and then back out from certain concepts. During this activity, most users took notes and verbalized what they were experiencing while working with the tools. Each session lasted on average around one hour. During this time, some focused on the manipulation of the features provided by the more complex visual tools (e.g., Sankey), while others gravitated toward working with simple visual tools (e.g., Mapping Table). Third, while working with the tools, participants often pointed to perceived overlap instances that they detected. In this context, we offer a preliminary qualitative observation: the visual tools appeared to have aided users in more confidently identifying perceived overlap cases at the sub-course levels, compared to using textbooks and syllabi that were too cumbersome and labor-intensive for them to tackle otherwise.

Classifying overlap. Once users managed to identify a perceived overlap, they often paused and reflected on it. First, they started analyzing the source of this overlap. The exploratory power of the visual tools equipped the users with the ability to go beyond the boundary of their own course content and contrast it with other courses they were unfamiliar with. This provided them with relevant contextual information that enabled them to decide whether this was a case of substantial overlap. Second, we observed patterns in the users' views on the perceived overlap. We saw instances in which instructors agreed with the students' view that a perceived overlap was occurring in their course and should not have been the case—i.e., negative overlap. But other instructors decided that it was acceptable for sister courses to cover similar and common concepts, and challenged the students' concerns over this, arguing that this is even beneficial for students—i.e., positive overlap.

Rectifying overlap. After identifying an overlap and classifying it, participants proceeded further to analyze the impact of the overlap on the curriculum. The look-up capabilities of the visual features enabled faculty to act on the problem. First, some argued that overlap can be reduced, as certain concepts should be covered only in specific courses. Others suggested the need for better coordination with other instructors to agree on who should teach what. Second, instructors who pointed to "positive" overlap instances often mentioned the need to keep such overlap and even extend it to other parts of the curriculum. One can make a reasonable observation that the visualizations provided not only a means of identifying perceived overlap, but also helped users rectify it by making more informed decisions. The visualizations achieved this by turning overlap from an abstract concept to a tangible one.

2) Visualization support for the overlap identification-classification-rectification process: We present in this part a detailed use case of how a specific visualization, the Sankey tool, was employed during the process of overlap identification, classification, and rectification.

Using Sankey for perceived overlap identification. Fig. 8 shows a potential sequence of steps to be followed using Sankey to identify perceived overlap. The list of courses in part (a) of Fig. 8 is extracted from the linked data source using a semantic search query. The user selects the course to explore in part (b). Then Sankey provides text-based information in part (c) about the total number of concepts covered in the course, along with the number of concepts shared with other courses in the curriculum. For example, in Fig. 8, the user can see that the principles of marketing course covers 343 concepts and has 50 concepts shared with 11 other courses in the curriculum. This textual information provides an initial indication of the presence of perceived overlap, via the number of concepts held in common with other courses. After absorbing this indicative information, the user can start visually exploring the conceptual links across the selected course by using the list of common concepts that may constitute substantial overlap among courses. The list of related courses is visualized on the right of the visualization. The explicit links that visually connect entities enable the participants to trace common concepts (often by pointing their fingers at the links on the computer screen). Referring back to Fig. 4, a few participants identified potential perceived overlap at the level of the "SWOT analysis" and "customer relationship management (CRM)" concepts that had thicker nodes than the others in the visualization (shown in parts (h) and (i) of Fig. 4). The size of the nodes at the course level in part (g) of Fig. 4 also highlights the degree of overlap at the course level—i.e., the number of common concepts. Thus, one can see the utility of the combined tools' textual and visual features helping identify the existence of perceived overlap, with an appropriate amount of granularity that allows one to drill down to the level of course topics and concepts.

Using Sankey for overlap classification. Once a perceived overlap is identified, users can start drilling further down to investigate the reasons behind such overlap. By hovering the pointer over a link, the Sankey visualization lets the user dynamically "highlight" the source and target of this link (see part (d) of Fig. 8). By hovering the pointer over a node, Sankey highlights the topics connected to this node by making them bolder (see part (e) of Fig. 8). In part (h) of Fig. 4, the visualization indicates that SWOT analysis is covered in the "company and marketing strategy: partnering to build customer relationships" topic of the "principles of marketing" course. At the same time, SWOT analysis is covered in: 1) the "optimization techniques" topic of the "managerial economics" course; 2) the "introduction to operations" topic of the "operations management" course; 3) the "strategic management" topic of the "fundamentals of management and organizational behavior" course; and 4) the "internal analysis" topic of the "strategic management" course. These examples were regarded by some faculty members as instances of unnecessary overlapping concepts in the curriculum. This made them think that covering this same concept in four courses in the curriculum was a mistake that should be rectified. In another example, some information systems instructors were interested in what the Sankey visualization showed. One instructor was not aware that the CRM concept that he covers in the "organizations and information systems" topic of his "foundations of information systems" course is also covered in two topics of the "principles of marketing" course: "managing marketing information to gain customer insights" and "creating and capturing customer value" (see part (i) of Fig. 4). Even though he had already heard students stress their familiarity with the CRM concept, now it was tangibly visible to him which other courses this concept was covered in, and from which topical perspective. He mentioned to us that he regarded positively the fact that the CRM concept that he covers from a technical perspective in his course is also addressed in a sister marketing context from a business perspective.

Using Sankey for overlap rectification. A few instructors who saw the perceived overlap manifested at the level of the "SWOT analysis" concept started questioning why such a concept is covered in both Marketing and Management, especially since most students take these courses in parallel during the same semester. Some instructors suggested that this concept probably should not be given during the same semester in two courses in parallel, especially if the content is identical. Instructors thought students are unlikely to regard perceived overlap among courses as building on each other when they are given in parallel. That is, in cases where students are exposed to the same concept, without an explicit discussion (or explicit contextualization by different instructors) as to how and why they build on each other, the students are likely to complain about perceived course overlap. Instructors proposed to eliminate such cases of perceived overlap. This shows how the deployment of digital visualization tools apparently helped instructors gain a deeper understanding of students' concerns over overlap, especially in cases where there appeared to be a substantial problem behind the perceived overlap. In certain other cases, instructors questioned the concern students expressed about the perceived overlap. In such cases, perhaps instructors should articulate explicitly to students why they are covering the same concept from a different perspective. The students are seeing any and all perceived overlaps as problematic, while from the instructors' point of view, many student-perceived overlaps were useful to keep in the curriculum. For example, the CRM concept that appears to students as a case of perceived overlap should be contextualized so that they can see the benefits of reemphasizing this concept from different perspectives. In other words, substantively speaking, this is not a "bad overlap."

C. Reflections on the process and outcome of handling perceived overlap

To draw lessons from the whole initiative and reflect on what general remedies we could recommend for the perceived overlap problem, we analyzed the think-aloud data from instructor interactions with the visualization tools. We employed qualitative data analysis techniques to code and extract recurring themes from these data [44]. After three rounds of coding, our analysis efforts converged on classifying the proposed rectification remedies for "perceived overlap" into two general categories: reducing repetition and extending reinforcement. That is, according to our analysis, after drilling down to better understand the substance of the overlap at the concept level, the instructors thought there was overlap among certain courses that they regarded as avoidable and negative. They used various terms, but these were largely synonymous, and we captured them under the umbrella term *repetition*. However, in other cases, the data analysis showed that instructors considered certain perceived overlap cases as positive, which helped students form a better and deeper cumulative understanding of concepts across courses. They labeled these with different but equivalent rubrics that we refer to in aggregate as *reinforcement*.

Interestingly, the instructors appeared to use an exploratory search process that allowed them to drill down, drill up, and then keep going back and forth when arriving at this classification of perceived overlap. Perhaps in retrospect, it may not be surprising that the instructors stumbled upon a dual classification system in which they deemed some instances of overlap as unnecessary repetition that could be eliminated, while judging that other cases of overlap amounted to necessary reinforcement for students. Nevertheless, we postulate that it was the deployment of the linked data visualizations that

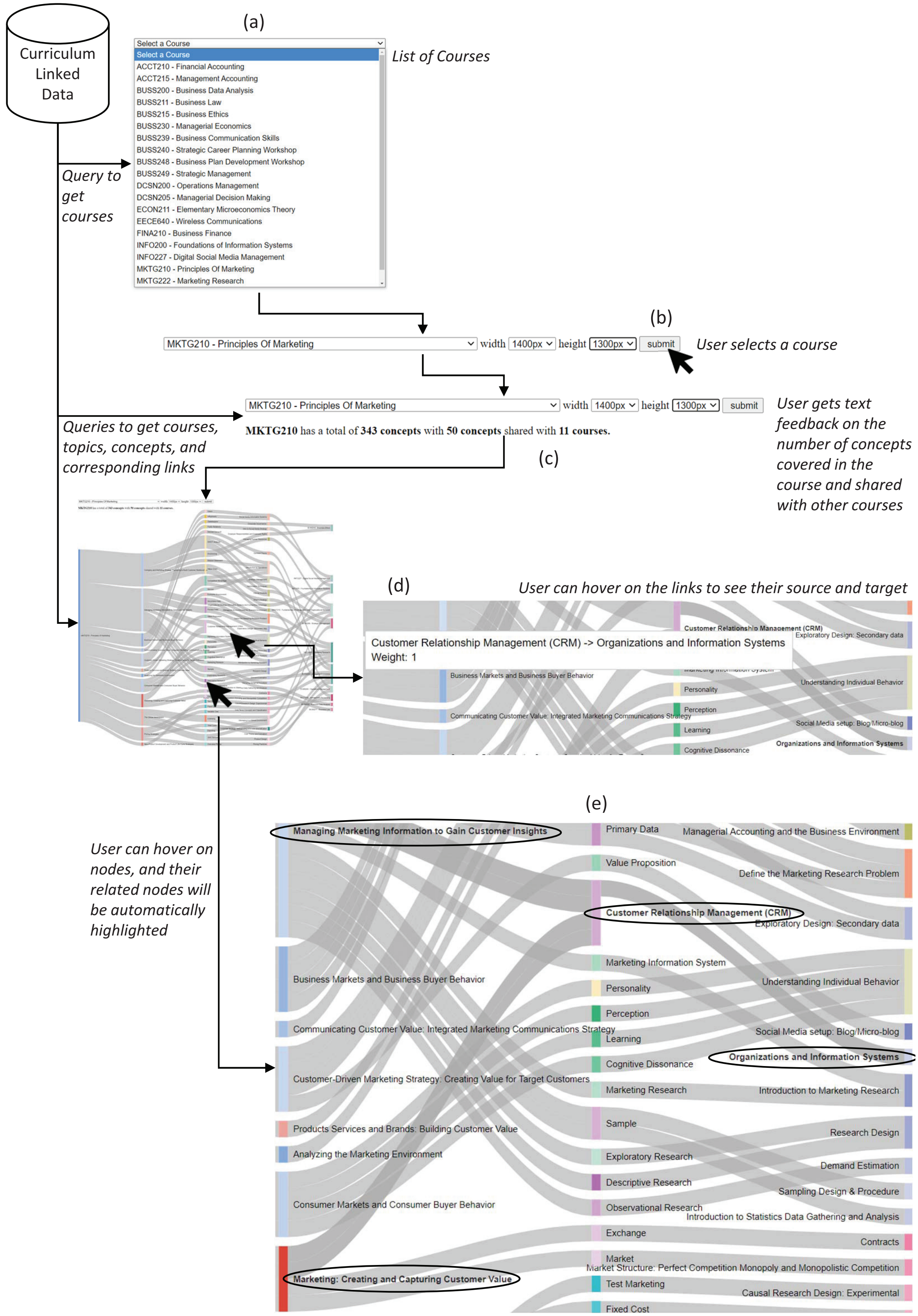

Fig. 8. Process of using the Sankey visualization to drill down and explore potential perceived overlap.

contributed to greater visibility of these instances of overlap, and thus led to the reconciliation of and closer alignment between instructor and student views of perceived course overlaps. That is, the visual mapping tools helped transform the perceived course overlap from an abstract concept into a tangible notion that could then be properly responded to and resolved via instructor actions.

Here we provide a glimpse of our analysis, including an overall count of how many instances of perceived overlap were tackled. First, we identified the statements in the text of the interviews in which the participants mentioned the two types of overlap that emerged from the data (i.e., repetition versus reinforcement). Second, we identified the statements referencing the four linked data visualizations. The processed interview data resulted in a total of 531 "overlap" related statements by the 25 participants. In total, the tools aided the participants in the identification of 318 instances of overlap as repetition, and 213 instances of overlap as reinforcement. The breakdown is as follows: 123 cases of overlap identified by the Treemap visualization, 126 by Forced-Node, 127 by Sankey, and 155 cases by the Mapping Table.

V. Discussion and Conclusions

With increasing competition and accreditation requirements, educational institutions are under pressure to maintain well-designed curricula, while also trying to meet the demands of their students. One particular challenge faced by curriculum administrators is the difficulty in handling students' complaints about perceived course overlap issues. One of the reasons for this problem is that students' perceptions of overlap often arise from the granular level of concepts (sub-course), while the course representations that instructors commonly adopt (e.g., course syllabi and catalogs) do not offer this level of granularity. This makes it hard for instructors and curriculum administrators to analyze perceived overlap as reported by students, since the former lack the ability to manage and explore concepts that exist in common among courses, and evaluate whether there is in fact substantial overlap and what to do about it.

To address this issue, we designed and developed in this paper an integrated digital environment that potentially enhances the productivity and scalability of earlier curriculum management tools (e.g., [2]). Specifically, the design of the underlying environment aims to provide the enhanced level of granularity that is required for effective detection and rectification of perceived overlap at the sub-course level, across the courses in the curriculum. The design further incorporates an ontology that allowed us to model curriculum content by semantically de-black-boxing the course entities, their topics, and the corresponding concepts as linked data. This ontology played a key role in defining and relating the concepts at the sub-course level, a prerequisite for representing perceived course overlap from the students' perspective. The management of curriculum linked data content was handled through a Semantic MediaWiki. The wiki was structured in line with the proposed ontology schema and assisted us in collaboratively capturing and storing linked data for 20 core courses, their 170 topics, and more than 2500 corresponding concepts. This would have been a daunting if not practically impossible task in the absence of digital tools. This wiki platform was further deployed to publish the curriculum content through semantic queries. The published linked data were then employed to develop four visualizations to provide a means for manipulating the curriculum through various diagrammatic, concept linkages, and user-customizable features. These visualization tools incorporated functionalities along a spectrum from simple visual features (e.g., rendering the curriculum connections in a tabular form using the Mapping Table tool), to more sophisticated and complex ones (e.g., a highly interactive network of curriculum concepts with their explicit connections depicted using the Forced-Node tool). The various features in the four tools were designed to give instructors and curriculum administrators the flexibility to employ the one they regarded as most appropriate for the task of detecting and rectifying overlap. This avoided straitjacketing them into using a single tool, which could have negatively affected their use of the digital environment.

The linked data visualizations were evaluated by observing and interviewing 25 instructors involved in the accreditation-mandated review of a business school curriculum. Our preliminary and exploratory analysis shows that the four visualizations were useful for detecting and rectifying perceived course overlap. The visualizations enabled instructors to detect the perceived "negative" overlap between common concepts, or what we refer to as *repetition*. These instances were candidates for potential elimination. In addition, the tools helped highlight the existence of "positive" perceived overlap that the instructors thought was useful, which we refer to as concept *reinforcement*. During the interviews, the participants were positively inclined toward the majority of the visual features designed and developed in this study. Some indicated that they were able to gain a deeper understanding of what a perceived overlap is. In other words, the abstract notion of perceived overlap appeared to have become more tangible and thus easier for the faculty to handle. They could visually track and see the overlapping concepts at a granular level, which was necessary for them to systematically identify the potential presence of perceived overlap as reported by students, and subsequently classify whether each case was a reinforcement type of overlap to be preserved or a repetition type to be eliminated. While the perceived overlap issue in the curriculum was a widespread student complaint looming over most courses in the curriculum, our study highlights the fact that the visualizations provided the means for a differentiated and more precise understanding of students' concerns about perceived overlap, going beyond course-level formulations. Therefore, we suggest that the proposed ontology and visualizations contributed to transforming overlap among courses from an abstract and fuzzy notion, to a more concrete, tangible, and precise construct.

It is important to be aware of some limitations of this research. First, while the study proposes an integrated framework, the evaluation focuses mainly on the four visualization tools. Further work is required to evaluate the different components of the proposed framework, including, for example, the usability of the wiki, and the completeness of the ontology scope and structure. Second, the study relies on feedback from course instructors. While instructors' views are important, we believe that capturing students' perspectives more directly can provide further insights into the impact of the visual tools on their perceptions of overlap. A third limitation of this study is that the data is collected from one business school. Conducting similar evaluations in other faculties could uncover faculty-dependent views of the notion of overlap that might potentially differ among university faculties.

Moving forward, this research can be extended in different directions. First, further studies can be conducted to understand the significance of variations in the visualization tools' support of positive versus negative overlap detection. For example, research could focus on asking: is the ability to detect negative overlap using the Forced-Node visualization significantly greater than the ability to detect negative overlap using the Treemap? Furthermore, do the visual features adopted to represent overlap (e.g., network-based versus text-based representation) have an impact on instructors' views of positive versus negative overlap? Additional research would be needed to answer such questions. Second, another research opportunity is to study other types of relations between courses (e.g., prerequisites) to explore their impact on the perceived overlap detection and rectification task. Third, this work can be extended to investigate the possibility of automating the overlap detection process and sending notifications for the faculty to respond to. Fourth, it may be worth investigating how the current tools proposed in this study compare to other approaches, such as topic and concept maps. Finally, it may be valuable to investigate the possibility of using the tools for solving curriculum-related issues beyond overlap. We foresee that the novel curriculum data visualizations will open new exploratory avenues that can make the process of performing university curriculum reviews more effective and efficient. We also believe that performing further studies of the impact of such tools on a variety of curriculum analyses and change processes is a promising future research direction.

Our work contributes to the curriculum modeling, mapping, and visualization literature in two ways. First, we contribute by developing a fairly generic approach to modeling curriculum linked data, coupled with four visualization tools. This approach allows instructors to explore course overlap at the granular level as perceived by students, and to resolve the identified cases of substantial course overlap. Second, we contribute by showing that perceived course overlap, when analyzed via the linked data visualizations in terms of its substance and classified either as repetition or as reinforcement, renders the fuzzy notion of overlap a concrete, tangible, and therefore resolvable problem.

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