What Will I Need this for Later? Towards a Platform for the Discovery of Intra and Inter-Module Content Relations

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Abstract: The large amount of knowledge in the different academic modules of bachelor and master studies renders it difficult for students to maintain the ”big picture” view, with the consequence of having finished a module without re-connecting to it in other attended courses, despite the existence of contextual relationships between them. The concept proposed in this work aims to provide a remedy for this problem by providing a graph-database-founded tool that shows all modules that also deal with that particular topic for a given keyword, additionally revealing the relationship within each of the modules. As such it provides the means for students and lecturers alike to discover interconnectedness among different modules, preventing an isolated view of each module, but an overarching perspective on the content learned during the studies, fostering connections among course content.

1 INTRODUCTION

”What will I need this for later?”, is a phrase that is overheard and stated by the authors of this paper during their time as students as well as now as teachers. Regardless of the tone and particular situation in which this question is asked, its core semantic remains the same: the wish to understand the relations of the currently absorbed knowledge (i.e. from a lecture or seminar) to the knowledge of future modules or even beyond in industrial or academic settings. While the primary force behind this question is driven by *curiosity*, it also implicitly serves another objective: to *introduce structure* to the masses of content permitting the linkage of knowledge *within* (intra-module relationship) and *across* (inter-module relationship) different modules as illustrated in Fig.1.

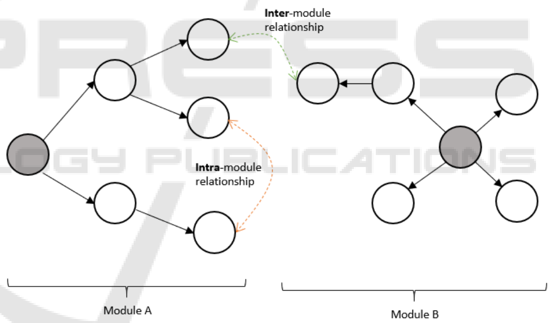

Figure 1: Illustration of relationships within a single module (orange arrow) and between two modules (green arrow).

To foster this approach towards the discovery of relations within and between modules, one can be tempted to state that this can simply be done by the lecturers in their respective courses. While indeed individual teachers address this aspect of ”What do you need it for later” in their lectures, this may not be ensured in general for the following reasons:
(a) Modules that are held by different research groups do not necessarily have an excessive exchange among each other, rendering it difficult to reference related concepts of another lecture in a different scientific research field of the same domain. As a concrete example: addressing aspects of the cell structure of bacteria within a microbiology course held by lecturers of a research group A and establishing a link to the cell biology course held by lecturers of research group B,
(b) The lecturers potentially follow different teaching concepts which shift the focus towards other important aspects,
(c) The lecturers may lack time in their modules to highlight relationships within and between modules.

An additional target is to motivate students to actively search for these relationships by themselves.

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This, however, raises the need for each student to go through the attended modules and their sheer volume of material to discover such linkages. While students have curiosity, we see a need to support them in introducing structure into the large volumes of content. This adresses a problem that has also been previously identified in (Alsaad and Alawini, 2020). To achieve this, we propose the **Related Work Connectome Project** (RWCP). It is an effort to provide a platform of related-work graphs, mindmap-like graph structures, for each module, where relationships within and between modules, denoted as *connectomes* can be discovered by students and academic staff alike through search queries. We further enhanced the scope from the connectome of modules to the connectome of related work sections of bachelor and master theses. The motivation behind the latter is to enable students to discover related work and possible connections among previously written theses by other students more efficiently.

The expected benefits of the RWCP are for once to simplify students' discovery of relationships within and between modules, augmenting and motivating them in their studies. Furthermore, another benefit lies in facilitating the discovery of relationships *within* modules for lecturers, in order to optimize the structure of their lectures, permitting fine-tuning of the content of their respective modules among different working groups. Lastly, it provides researchers further opportunities to trace and connect content across different working groups, or in general, research domains, fostering *interdisciplinary* scientific endeavors.

Throughout this work, we will use the terms *related-work graph*, *mindmap*, *concept map*, or *graph* synonymously, although they may be used with different preferences among the literature of their respective domains. The same condition applies to the term *module* which is used interchangeably with *course* or *lecture*.

This position paper aims to present the idea of the RWCP, elaborate on the related work and in this context also on mindmaps, and critically discuss potential challenges and expected benefits.

2 RELATED WORK

The initial idea for the RWCP is rooted in insights gained from student evaluations of different courses, namely the master modules *Big Data Management and Analytics*, *Advanced Data Mining and Machine Learning*, *Knowledge Discovery and Data Mining* and the bachelor module *Database Systems*. In these modules, we introduced simple mindmaps within the past four semesters and received thoroughly positive feedback via the EvaSys evaluation. This stimulated the investigation into related work to the RWCP. At the same time, the question of which experiences other students and educators made in different domains and at different levels of education with mindmaps-based approaches arose. In the following, we elaborate on related work addressing different aspects revolving around mindmaps and the role they play in education.

Mindmaps in the Context of Efficiency and Student Involvement. Since this position paper is founded on the concept of mindmaps, a core question is: Can we observe an increase in learning efficiency? And do mindmaps contribute to an increased involvement of students in course activities? These particular questions have been addressed in a study by (Gagić et al., 2019) where the authors also aim to capture the perception of the mental effort of students in a group with and in one without utilizing mindmaps. Additionally, they investigate the results concerning performance in a test at the end of the study phase for both groups. The target age group in the conducted study were elementary school students learning about the subject of physics. The results show that the group that utilized mindmaps had higher results and at the same time exhibited a lower perceived effort compared to the control group. A more recent work by (Fung and Liang, 2023) also supports the idea that collaborative mindmap construction at elementary school level enhances student motivation and, as a consequence, also participation.

On the Benefits of Mindmaps in Higher Education. While the previous study is based on groups of elementary school students, in the review paper of (Machado and Carvalho, 2020) the authors investigate the observed effects of mindmaps (denoted as concept maps) in the context of higher education (undergrad students) in the literature landscape. The authors identify that concept maps are beneficial with regards to the development of critical thinking skills and that they facilitate transference between theoretical and practical content. The enhancement of critical thinking skills has also been observed independently in a study on young children in more recent work by (Polat and Aydın, 2020) serving as a cautionary indication that the improvement of critical thinking skills while utilizing mindmaps can be observed independently of age.

The authors further state that the fact that concept maps develop meaningful learning skills can be observed and are used by students for learning progress and assessment as well. The aspect of assessment in the context of higher education has also been investigated in the domain of humanities within the work of (Kandiko et al., 2013), where the authors come to the same conclusion: Concept maps can help assess the individual learning progress of students. This insight is of special interest since the first feedback that we received by students after oral or written exams, emphasized that mindmaps prompted them to create an individual learning plan which, in turn, acted as a means to capture the learning process. Another insight from the authors by reviewing papers on this topic was that concept maps promote technology inclusion. This is indeed an aspect that supports our concept of a platform in the scope of the Related Work Connectome Project (RWCP). The authors of (Machado and Carvalho, 2020) however also discovered potential challenges, namely of integrating concept mapping in academic practices. More specifically, among the literature it could be observed that students exhibit difficulties in concept and link selection. Alongside, students also faced challenges with software. Regardless of the issues across the reviewed literature, concept maps were identified to be well accepted by students in higher education. The challenges mentioned motivated us to identify and discuss potential difficulties and pitfalls of this concept as seen in Section 4.

On collaborative Multi-View Aware Concept Map Design. Moving one step further, the authors of (Picardi et al., 2020) provide the prototype of a platform that enables a digital and collaborative approach to conceptualizing concept maps. Besides the design of an online tool, a crucial aspect addressed by the authors is the fact that different students may have different views on a topic (in our case: module/course content relations). This is particularly of relevance when students create concept maps in assignments or in the context of tutorials.

Relationship-Tailored Representation of Teaching Content. One endeavor towards a relationship-tailored representation of teaching content is proposed in the concept of learning paths by (Yang and Dong, 2017), proposing pathways through several units of learning (UoL). Two other more recent contributions provide automatic extraction of mind or concept maps from videos (Vimalaksha et al., 2019) or text slides (Atapattu et al., 2017). Contrary to the aforementioned related work, our proposed concept does not aim to extract mindmaps but provides the means to query and hence to explore relations within and between mindmaps. However the creation of mindmaps e.g. by students is a vital exercise to develop the skill of distilling the relevant aspects of a module and to structure them. As a consequence, we discuss in Section 4 the necessity to train students in the conceptualization of mindmaps.

On the Necessity for an Inquirable Platform of Course Content Structures. To summarize, the related work so far addresses the benefits of mindmaps and their synergetic effect when created in groups of students. Furthermore, there is previous work that elaborates on the aspect of relationship-tailored representation of course content. What the related work, to the best of our knowledge, does not provide is a platform that (a) contains readily available mindmaps that represent modules and their relationships within and between different courses and (b) that is queryable, meaning that it yields only parts of mindmaps and its connections that are relevant for the user (e.g. student, teacher, scientist). This is where we aim to propose a concept with the RWCP.

3 THE RELATED WORK CONNECTOME PROJECT

The very foundation of the RWCP are single graph structures that represent a module:

Definition 1 (Related-Work Graph)
A related-work graph is a directed n-ary tree $T = (V,E)$ consisting of vertices V and edges E. The root of the related work graph is denoted with Ω. The depth d of the graph T is $d = 0$ at the root and increases with each successor node.

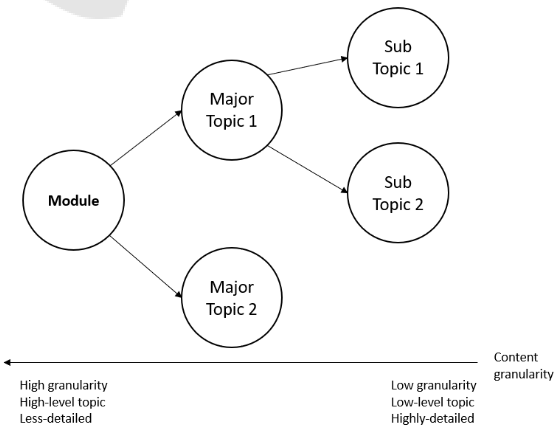

Figure 2: Illustration of the decreasing content granularity from center of the related-work graph to the leaf nodes.

In this context the semantics behind the term *con-*

tent granularity is as follows:

Definition 2 (Content Granularity)
In a related-work graph $T = (V,E)$, the direction from the root node Ω (of a module) to the leaf nodes bears the semantics of decreased granularity with an increasing depth d. Here the term granularity refers to a transition from high-level (less detailed/coarse/granular) to low-level (more detailed/fine) terms of the module.

To illustrate the concept of granularity we can take the module *"Database Systems"* as the root node. Being the most high-level node (we just know that it is about databases at this point), to its next outer node e.g. *"SQL"* being a more specific term up to *"Relational Algebra"* being a more detailed term in the context of the SQL language. A schema of the granularity within a related-work graph can be seen in Fig 2.

As a concrete example, Fig 3 depicts a specific cut-out of the module contents of "Advanced Data Mining and Machine Learning", revealing the details at lower granularity, meaning a higher detail of the content, showcasing an exemplarily intra-module relation that reveals a connection between two nodes (items) of the mindmap that were taught in different topics.

With these definitions as ground work, we continue to provide a definition for the concept of intra- and inter-module relations:

Definition 3 (Intra- and Inter-Module Relation)
Given two related-work graphs $T = (V_t, E_t)$ and $S = (V_s, E_s)$. An intra-module relation $r_t = (v_{t_i}, v_{t_j})$ with $\{v_{t_i}, v_{t_j}\} \in V_t$ is an edge in T that short-circuits T by creating a cycle within T that is characterized by a node v_{t_j} having an in-degree $deg(v_{t_j}) > 1$. An inter-module relation $r_{t,s} = (v_{t_i}, v_{s_j})$ is an edge between T and S that is also characterized by a node v_{s_j} having an in-degree $deg(v_{s_j}) > 1$.

Finally we can now provide a definition of a connectome:

Definition 4 (Connectome)
. A connectome is a database $DB = \{G_1, ..., G_n\} \cup \{r_1, ..., r_k, r_{1,1}, ..., r_{m,n}\}$ of at least one graph $G_i = (E_i, V_i)$ up to n total graphs (n denoting the number of graphs in a DB) of potentially different granularities and a set of intra- and inter-module relations.

With the concepts of a related-work graph, content granularity, intra- and inter-module relation and connectomes we have the means for a graph database for students and lecturers alike to discover relationships between modules. A first sketch of the pipeline of the RWCP can be seen in Fig. 4 with Neo4j as the graph database of our choosing. In this pipeline a query is submitted via frontend to a Neo4j database containing the connectomes. The result of the query is returned from the backend and visualized for the user. The connectomes can be constructed by lecturers alone or together with students.

4 DISCUSSION POINTS

Since this position paper represents an arguable opinion on the idea of the Related Work Connectome Project (RWCP) we deem it indispensable to elaborate on the different challenging facets that accompany this idea. In the following, we name and discuss a set of questions that arise in the context of related-work graphs and that provide a challenge in the light of different aspects.

What are the Expected Benefits of this Concept?
Structured Module Content Overview.
The RWCP establishes a systematic arrangement of module content within dedicated graphs, facilitating a structured and organized representation of the subject matter.
Analytical Tool for Intra- and Inter-Module Relations.
The utilization of graph databases in RWCP serves as an analytical tool, enabling the investigation of both intra- and inter-module relationships. The database structure provides the means to explore the intricacies of connections within and between modules.
Support for Learning Processes.
The RWCP aims to assist students in their learning processes through the implementation of graph databases and associated queries. This approach seeks to enhance the navigability of complex concepts, potentially contributing to more effective learning outcomes.
Facilitation of Module Development for Educators.
Educators can benefit from RWCP as it offers a platform for the ongoing development and refinement of modules. The insights derived from the graph database can empower teachers in the iterative enhancement of their teaching materials.
Opportunities for Interdisciplinary Exchange.
RWCP has the potential to create an inclusive environment for collaborative exchange among stakeholders from diverse domains. By fostering interactions and knowledge sharing, the proposed approach can contribute to an enriched academic experience.

Can this Concept not be Exercised Entirely by Students? The platform and related-work connec-

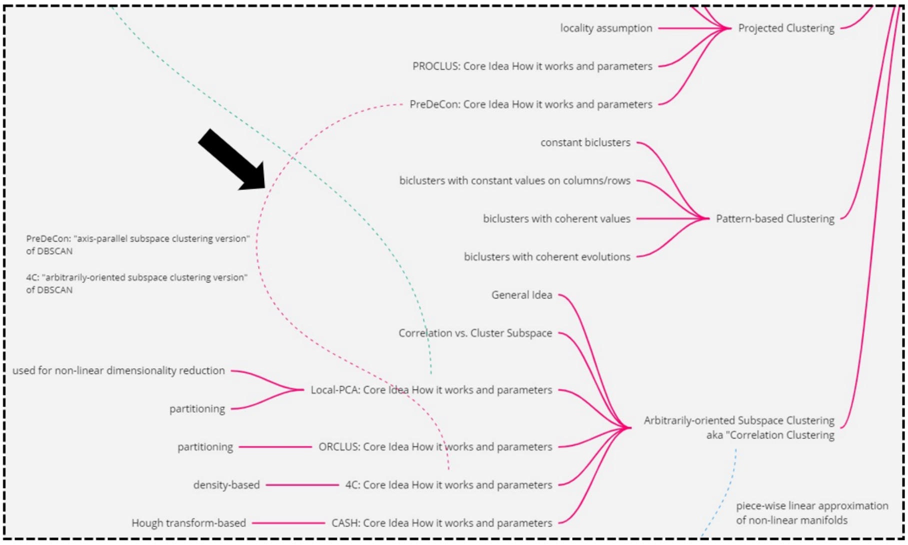

Figure 3: Example of a partial mindmap representing parts of the structure of the "Advanced Data Mining and Machine Learning" module, with annotated intra-module relation (black arrow).

tomes are provided as integral components. Students are afforded the opportunity to engage in designated exercises, coupled with comprehensive training, aimed at distilling graphs from content. This training is designed to improve and practice the identification of relationships within and between modules. The overarching objective is to enhance their capacity to discern connections across the literature/content landscape, concurrently with the skill of compressing lecture information into a more succinct structure. This compression process is intended to enable more efficient learning outcomes. In a recent survey the authors of (Jackson et al., 2023) concluded that among the related literature, one insight is that the design of mindmaps by students can reveal the understanding of the topic and serve as a way of assessment of the learning progress for the course instructors.

What is the Estimated Effort in Maintaining the Platform, Especially the Data? The inquiry pertains to the anticipated effort associated with maintaining the proposed platform, with a specific focus on data management considerations. The facets under scrutiny encompass IT maintenance and the periodic updating of software and hardware alike. Furthermore, given the evolving nature of module content, a crucial aspect involves regular updates of related-work graphs. Additionally there exists a potential opportunity, possibly internal, for teaching staff to monitor the evolution of lecture content, tracing the lineage of both module content and structure. A noteworthy consequence of neglecting the timely update of graphs is the potential erosion of student confidence in the platform's reliability.

What About the Individual Level of Granularity? The issue of granularity at the individual level raises pertinent considerations within the Related Work Connectome Project (RWCP), warranting careful examination:

Variability in Student or Teacher Granularity.
The granularity of graphs may differ among students and teachers, introducing potential disparities. Such discrepancies might lead to a lack of expected similarities in the graphs. However, what seems as a disadvantage at first sight, is actually an opportunity: In the work of (Nuninger et al., 2019) and (Goy et al., 2017) the authors elaborate that different individuals may have different *views* on content, and as a consequence, in the context of mindmaps, different mindmaps may emerge from different individuals. One objective can be, according to (Nuninger et al., 2019), to encourage exchange between individuals to achieve a harmonized view that can be thought of as the smallest common denominator of connections. One potential outcome of this harmonization process is that involved individuals mutually obtain (at least parts of) the view of others.

Challenges in Harmonizing Granularity.
Attempts to harmonize granularity face challenges, as quantifying granularity in a standardized manner proves difficult. This poses a hurdle in achieving a consistent level of detail across graphs.

Annotative Solutions for Granularity Differences.
A plausible solution involves empowering both teachers and students to annotate or extend graphs as they see fit. This approach accommodates variations in granularity, making visible the differences that may otherwise remain obscured due to individual nuances.

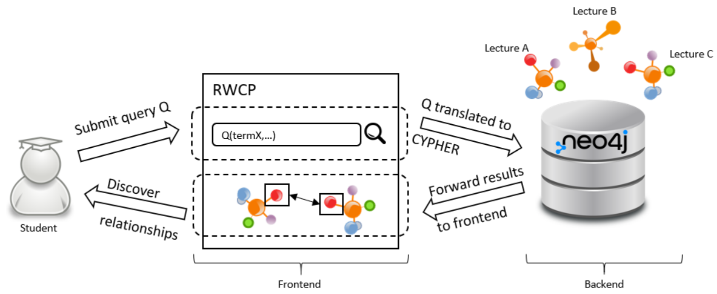

Figure 4: Pipeline of the RWCP with the interactions between user, frontend and backend.

Potential for Graph Expansion.
An inherent risk is the potentially substantial growth of graphs. While this can be a significant concern in conventional mindmaps, the impact is mitigated within the RWCP context. Queries selectively visualize relevant portions, mitigating the criticality of overall graph expansion.

In essence, the consideration of granularity at the individual level within the RWCP necessitates nuanced strategies, such as annotation and selective visualization, to address variations without compromising the project's objectives, especially in the light that different views of individuals can impact granularity *and* the established relations within and between modules.

If We Allow Teaching Staff and Students to Enhance or Annotate the Graphs and Their Connections, How Can We Ensure that the Data in the Graph Database Does not Get Broken by e.g. Wrong Content? Addressing the potential challenge of maintaining data integrity within the graph database when permitting teaching staff and students to enhance or annotate graphs and connections requires thoughtful consideration. Several strategies could be employed:
Moderation by Teaching Staff.
One approach involves moderation by designated teaching staff. However, this introduces an associated overhead, necessitating additional resources for effective oversight.
Majority Vote by Students.
An alternative method is to implement a majority vote system among students. Given the shared interest in maintaining accurate and valuable content for studies, it is presumed that the majority of students would be motivated to uphold a certain quality standard for the graphs.
Motivation for Quality Assurance.
Leveraging the students' intrinsic motivation for high-quality content, this approach not only ensures data integrity but also fosters discussions among students. Such interactions contribute to their preparation for lectures and exams, furthering a collective revision of lecture content. Additionally, it provides valuable insights for teaching staff into students' comprehension and interpretation of the material.
Drawing Parallels with Wikipedias Editing Concept.
The concept can draw inspiration from Wikipedias model of collaborative editing, emphasizing collective contributions to content. However, it is essential to acknowledge and manage the potential risk of 'edit-wars'— a scenario where conflicting edits may pose challenges to maintaining data coherence.
Automated Assessment of Mindmap Quality.
This approach comes with the pre-requisite of measures that capture the quality of "how good" a mindmap is. A first endeavor has been made by (Cañas et al., 2015) who investigate properties by which the quality of concept maps can be assessed. The formalization of objective(s) that provide measures for the quality of mindmaps can then be utilized in well-known classification techniques in the machine learning domain up to the latest state-of-the-art deep learning frameworks.

To conclude for this aspect, the integration of moderation, majority voting, and leveraging students' intrinsic motivation can collectively serve to uphold data integrity while fostering an environment of collaborative learning and content improvement within the Related Work Connectome Project.

Can Students Exploit the RWCP? What Would be the Consequences and How Severe Would They Be? Exploring the potential for students to exploit the capabilities of the Related Work Connectome Project (RWCP) raises critical considerations and necessitates a nuanced evaluation of consequences:
Strategic Query Exploitation.
Students may be inclined to craft queries highlighting modules with the largest overlap, strategically choosing courses that minimize exposure to new content. While initially perceived as a concern, this approach could also reveal sequences of modules that logically build upon one another, motivating students to pursue a coherent academic direction, such as in the domains

of cell biology, data mining, or quantum physics.
Identification of Overlaps.
The RWCP may showcase substantial overlaps between modules, within the same research group or across different groups. While potentially advantageous for fostering collaboration, it prompts the need to scrutinize whether these overlaps are essential. This analysis can lead to productive exchanges within or between research groups, allowing for an investigation into the necessity of the overlaps. If redundant, this insight can guide the replacement of content with new, potentially more pertinent teaching material.

While the potential for students to exploit the RWCP exists, it simultaneously presents opportunities for students to strategically align their academic pursuits and for research groups to collaboratively assess and enhance the relevance of teaching content. The consequences are multifaceted, necessitating a balanced evaluation of both challenges and potential benefits.

How can Users State Queries to the RWCP Platform? The process of formulating queries to the Related Work Connectome Project (RWCP) platform is a crucial aspect that warrants careful examination within the context of user interactions:
Initial Settings-Based Querying.
Users initiate the query process by selecting specific settings, providing a structured starting point for interacting with the database. This approach allows for a tailored exploration of relevant information based on user-defined parameters.
Investigation into Natural Language Queries.
A pertinent research question involves the feasibility of users articulating arbitrary queries in natural language to extract meaningful results from the RWCP platform. This inquiry seeks to understand the extent to which users can leverage natural language interfaces for querying, potentially enhancing accessibility and usability.
Phrasing Queries for Discovery.
An essential aspect of the investigation involves understanding and teaching the formulation of queries in the platform's context. This effort aims to demystify the process, motivating both students and scientists to articulate queries effectively. By fostering an understanding of query phrasing, the platform encourages users to actively explore and uncover patterns and relationships within and between graphs.

The mechanism for user-driven queries in the RWCP platform involves both structured settings-based querying and an exploration into the potential use of natural language. Teaching the art of query phrasing becomes pivotal in cultivating a user base motivated to discover intricate patterns and relationships within the platform's rich dataset.

Is a Prior Introduction to that Platform Necessary? The necessity of a prior introduction to the Related Work Connectome Project (RWCP) platform is a pertinent consideration, even as efforts are made to maintain simplicity comparable to modern search engines or language models like ChatGPT (Brown et al., 2020):
Vitality of Basic Platform Introduction.
While the overarching objective is to emulate the simplicity of contemporary search engines or language models, it remains imperative to offer a concise introduction to the RWCP platform and its fundamental usage. This introduction serves as a foundational step to ensure that users are acquainted with the platform's functionalities.
Flexible Introduction Methods.
The introduction can be delivered through various modalities, including short courses dedicated exclusively to platform usage, brief overviews integrated into all modules within a 10-15 minute timeframe, or succinct tutorial videos. The flexibility in the delivery of this introduction caters to diverse learning preferences and optimizes the accessibility of platform guidance.

Can the Relationships Within and Between Modules not Be Extracted Through LLMs? The examination of whether relationships within and between modules can be effectively extracted through Large Language Models (LLMs) (Brown et al., 2020) is a nuanced inquiry, considering the current landscape of advanced language models:
Emergence of Large Language Models.
The current era has witnessed a surge in the popularity of LLMs, exemplified by platforms like ChatGPT. These models have demonstrated significant prowess in diverse language-related tasks.
Limitations of LLMs in Capturing Relations.
However, despite their proficiency, LLMs may face limitations in accurately capturing intra- and inter-module relations. To the best of our knowledge, existing LLMs may lack the capability to generate comprehensive graphs depicting these intricate relationships. As a small test that can be conducted by the reader, we have asked ChatGPT if it is capable of generating mindmaps from some given lecture content, to which it responded that it can not create visual representation. Alternatively a set of bullet points with indentations is proposed which fails to illustrate more complex inter-module relations. Therefore, as for now, ChatGPT can not extract or generate a mindmap

from given lecture slides.

Value of Manual Discovery of Relations.

The manual discovery of relations within and between graphs, promoted by students and teachers, offers valuable insights. This process enables a multifaceted exploration, providing diverse views on potential core elements of modules. Such insights, currently beyond the reach of LLMs, contribute to a more nuanced understanding.

5 CONCLUSIONS

In this position paper, we propose and discuss the concept of the Related Work Connectome Project, an approach that is aimed to provide students and lecturers alike the discovery of structures within a module and between different modules. While on a first glance this concept seems like ”yet another platform” it is founded on various well-researched aspects like concept maps, collaborative design of concept maps, and learning pathways. As the idea behind the RWCP can be quickly sketched, the emerging challenges as provided in Section 4 go far deeper and reveal interesting challenges and opportunities to be discussed. We hope that this idea paves the path for enhancing research of intra- and inter-module relations, but first and foremost fosters an active discussion and exchange on the challenges and opportunities of such an endeavor.

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