School of Computer Science and Engineering

Faculty of Engineering

The University of New South Wales

Building a Meta Learning Management System

by

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Abstract

This thesis aims to address the limitations in the repurpose and reuse of digital assets and content in current Learning Management Systems (LMS). Through examining popular existing learning management systems where course contents are reused with limited flexibility, we will propose, develop and evaluate a Meta Learning Management System. This is a system which focuses on a more fine-grained view of educational resources. The fundamental idea revolves around using a topic-based graphical structure to structure and represent learning materials (e.g. a lecture video), where a topic is defined as the basic building block of a course. The system will provide the ability to manage topics and their learning materials in a graph where new topics and learning materials can be added to the graph and reusable learning objects can be easily extracted from the graph to be used and reused for courses in existing Learning Management Systems.

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Chapter 1

Introduction

A Learning Management System is a platform for learning and storing digital learning materials. Its purpose is to facilitate student learning, course management as well as assessment and report of student performance. Popular existing platforms include Canvas, Moodle, WebCMS, Open Learning.

On many existing Learning Management Systems, when a new course is to be created by a course convenor, if this course comes from a previous offering of the same course, course convenors may be able to reuse learning materials by "importing" them. However, if new content were to be added or a new course not previously offered is to be created, they often need to create all course content from scratch. On many occasions, there may already exist learning materials other academics may have created for other purposes (e.g. other courses) which may cover some of the same content.

As a result, a lot of learning content is repeatedly created which is a costly and inefficient process for course convenors. A small example in UNSW's School of Computer Science and Engineering is that COMP1511 and COMP2521 both teach Abstract Data Types with their own resources.

Some existing Learning Management Systems attempt to allow some degree of repurposing and reusability. Canvas and Moodle are two of the most popular Learning management system platforms amongst top universities. Both allow the reuse of an entire course or specific content

from past courses when creating a new course via some inbuilt mechanism which allows the export and import of the content and materials. Even then, there is limited flexibility and lack of support. Course convenors can often only easily reuse courses and specific contents they themselves have created due to numerous reasons such as lack of information about other existing content. In short, there is no clear, standardised course structure and process for sharing, leading to content only being reused across the same course being taught by the same course convenor across different offerings.

In order to tackle these problems, the following specifies a workflow proposed involving a Meta Learning Management System.

There are three stakeholders in the full workflow (Figure 1.1) Academic, Course Convenor and Student.

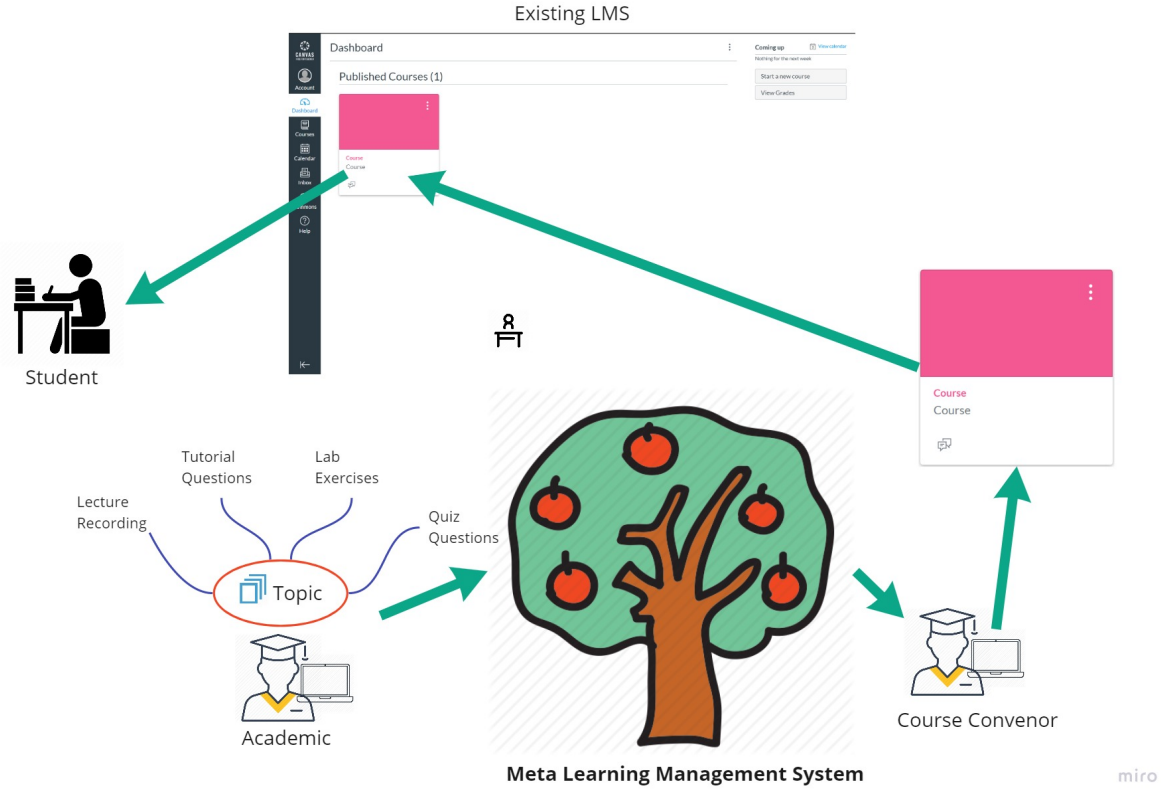

Figure 1.1: The overall workflow involving the Meta Learning Management System.

1. An **academic** creates learning materials for individual topics and populates the Meta LMS.
2. A **course convenor** creates their course by taking learning materials from the Meta LMS and populates it into their course in their existing LMS used by their institution.
3. A **student** consumes this content via their existing LMS interface.

The Meta LMS will act as a system to provide the ability to easily repurpose and reuse digital assets and contents for courses. Reusability in this context has 3 separate meanings:

- Reusable across multiple offerings of the same course
- Reusable across multiple courses
- Reusable across courses of varying delivery modes e.g. face to face, fully online, short courses

Within this workflow, the focus of this thesis is on how academics create and store learning content on a Meta Learning Management System as well as how course convenors select resources from this system to populate an existing LMS.

Overall, the aim of this thesis is *to maximise the reusability of learning content and improve the efficiency in the course creation workflow for academics and course convenors through designing and developing the Meta Learning Management System. That is, a centralised system consisting of a standardised structure for storing learning content which facilitates a more student-learning friendly structure and enables academics and course convenors to create, store, export and easily share and reuse learning content in the creation of different courses.*

In summary, the main contribution of this thesis are:

- The introduction of a new workflow involving the Meta LMS for academics and course convenors in creating a course
- The design and development of a multi-dimensional network graph structure based on the notion of fine-grained Topics in representing knowledge and learning content.

- A standardised structure to facilitate academics in the organisation of learning content within a Topic based on existing models of student's learning process.
- The introduction of modular exportable Topic packages which can be combined together to form various courses for a Learning Management System used.
- Abstracting the creation and organisation of knowledge and learning content away from the creation of courses on Learning Management Systems, allowing content creation to be independent from course design and delivery.
- The development of a functioning proof of concept involving all of the above as well as other additional features which facilitate the content and course creation workflow of academics and course convenors.

This thesis is structured as follows. In Chapter 2, we provide a literature review examining popular existing Learning Management Systems. In Chapter 3, we will discuss the approach to this thesis. In Chapter 4, the execution of the project including the technical implementation details of a proof of concept for the Meta LMS will be covered. In chapter 5, a walkthrough will be provided in regards to the implemented Meta LMS. In Chapter 6, we will discuss the steps taken to analyse how close the implemented proof of concept is from achieving the overall aim. Lastly, Chapter 5 will conclude this thesis.

Chapter 2

Background

2.1 Context

As aforementioned, a Learning Management System (LMS) is a platform for learning and storing digital learning materials. Its purpose is to facilitate student learning, course management as well as assessment and report of student performances. Here are some examples of popular Learning Management Systems:

- Instructure Canvas
- Blackboard Learn
- Moodle
- Desire2Learn (D2L) Brightspace
- Sakai
- WebCMS3
- Open Learning
- Smart Sparrow

- Blackboard
- Xuetangx Cloud
- Google Classroom
- Adobe Captivate Prime

As of Spring 2020, comparing between universities in regions of US, Canada, UK and Australia, the top 5 Learning Management Systems are Blackboard Learn, Instructure Canvas, D2L Brightspace, Moodle and Sakai as shown in Figure 2.1 below.

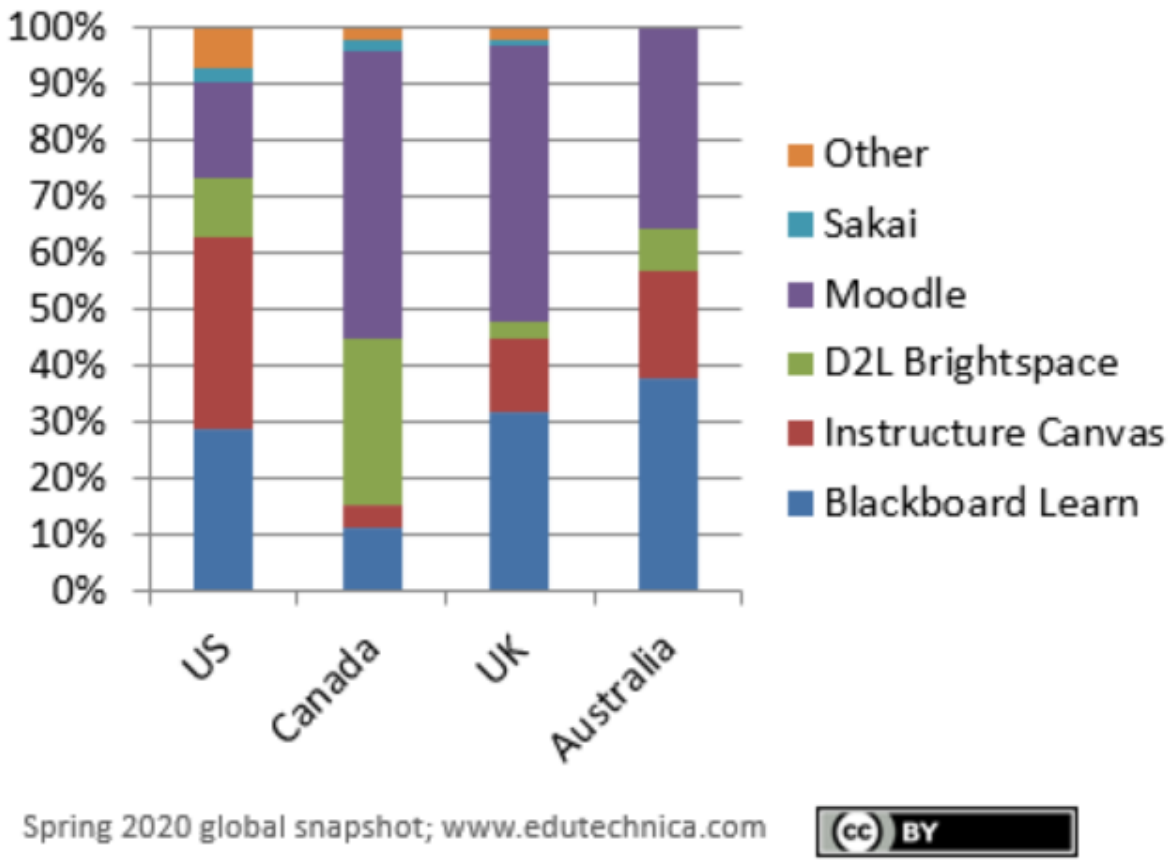

Figure 2.1: Popularity of LMS in different regions

As it can be seen, Moodle is the most popular Learning Management System amongst universities in Canva, UK and Australia. On the other hand, Instructure Canvas is the most popular Learning Management System in the US.

Four out of five of the top five universities of QS World University Rankings 2021 (MIT, Stanford, Harvard, Caltech, Oxford) currently use or are transitioning into Instructure Canvas as their learning management system.

At UNSW, Moodle is currently used as the main Learning Management System. Additionally, in the School of Computer Science and Engineering, WebCMS3 is also used.

To get a broader perspective, these are what some of the top universities outside of the majority native english speaking countries use as their learning management system:

- Eth Zurich uses Moodle
- National University of Singapore uses LumiNUS which is a system they have developed themselves
- TsingHua University and most other top universities in China uses Xuetangx Cloud
- University of Hong Kong uses Moodle
- University of Tokyo uses ITC-LMS which is a system they have developed themselves

2.2 Literature Review

This section explores the various Learning Management Systems that are most popular amongst higher education institutions. The main focus will be to observe how these systems address the concept of reusability and allow learning content to be reused. To provide more background, the systems' philosophies and features will be briefly considered.

Specifically, Instructure Canvas, Blackboard Learn, Moodle, Desire2Learn Brightspace, Sakai and WebCMS3 will be examined. Relevant systems such as authoring tools and Charles Sturt University's Topic Tree will also be discussed.

2.2.1 Instructure Canvas

The Canvas open-source web-based Learning Management System (https://www.instructure.com/canvas/en-au) is a fast-growing platform which has become the most popular choice of Learning Management System amongst higher education in the US. It features the management and customisation of courses, analytics and statistics as well as internal communication tools for courses and users.

Canvas' philosophy has been to empower teachers and engage students by building the system that simplifies the process and makes education more efficient and effective. They are focused on "student-centred learning" where they aim to "develop students' capability for self-directed, lifelong learning by granting them more choice, control, and responsibility". Canvas also takes pride in being the "Most Pedagogical Flexibility of the LMS's" as quoted from one of the surveys they have conducted.

In terms of the degree of reusability and flexibility when a course is created on Canvas, the system allows the direct reuse of an entire course as well as the option to select particular parts of the course. As shown in Figure 2.2, there are options to import and export course content where importing course content provides a choice of directly importing from an existing course accessible on the system or to import a local package.

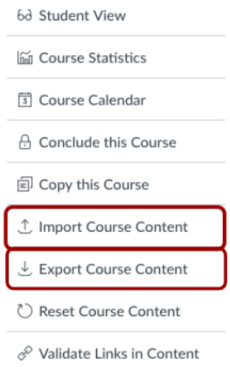

Figure 2.2: Course Menu Options on Canvas LMS

Direct import from an existing course gives the flexibility to select all or any parts of the course

whether it is a group of content (e.g. all the quizzes for the course) or a very specific part of the course (e.g. one particular page of content) as shown in Figure 2.3 and Figure 2.4 below.

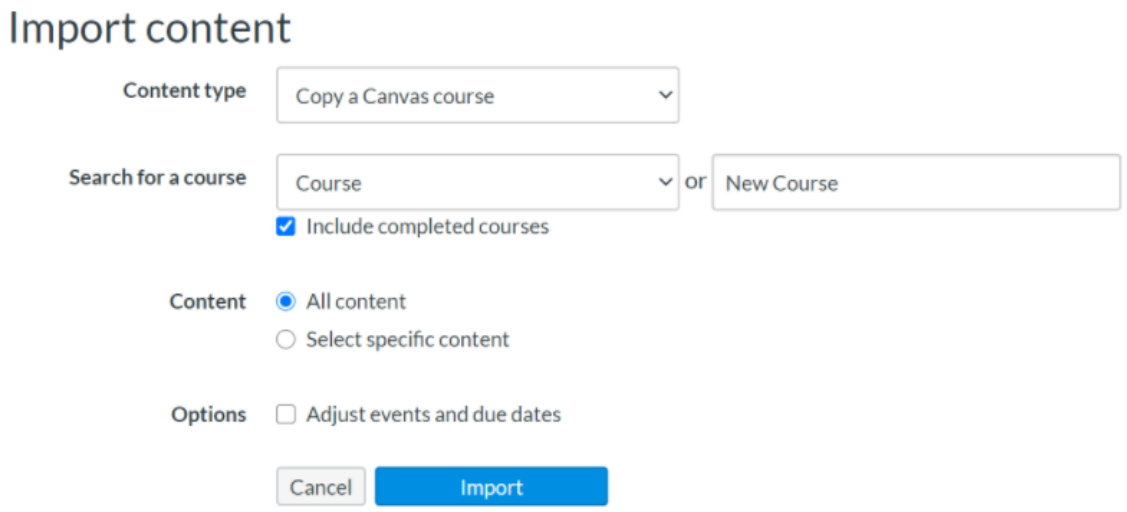

Figure 2.3: Importing content from an existing course on Canvas LMS

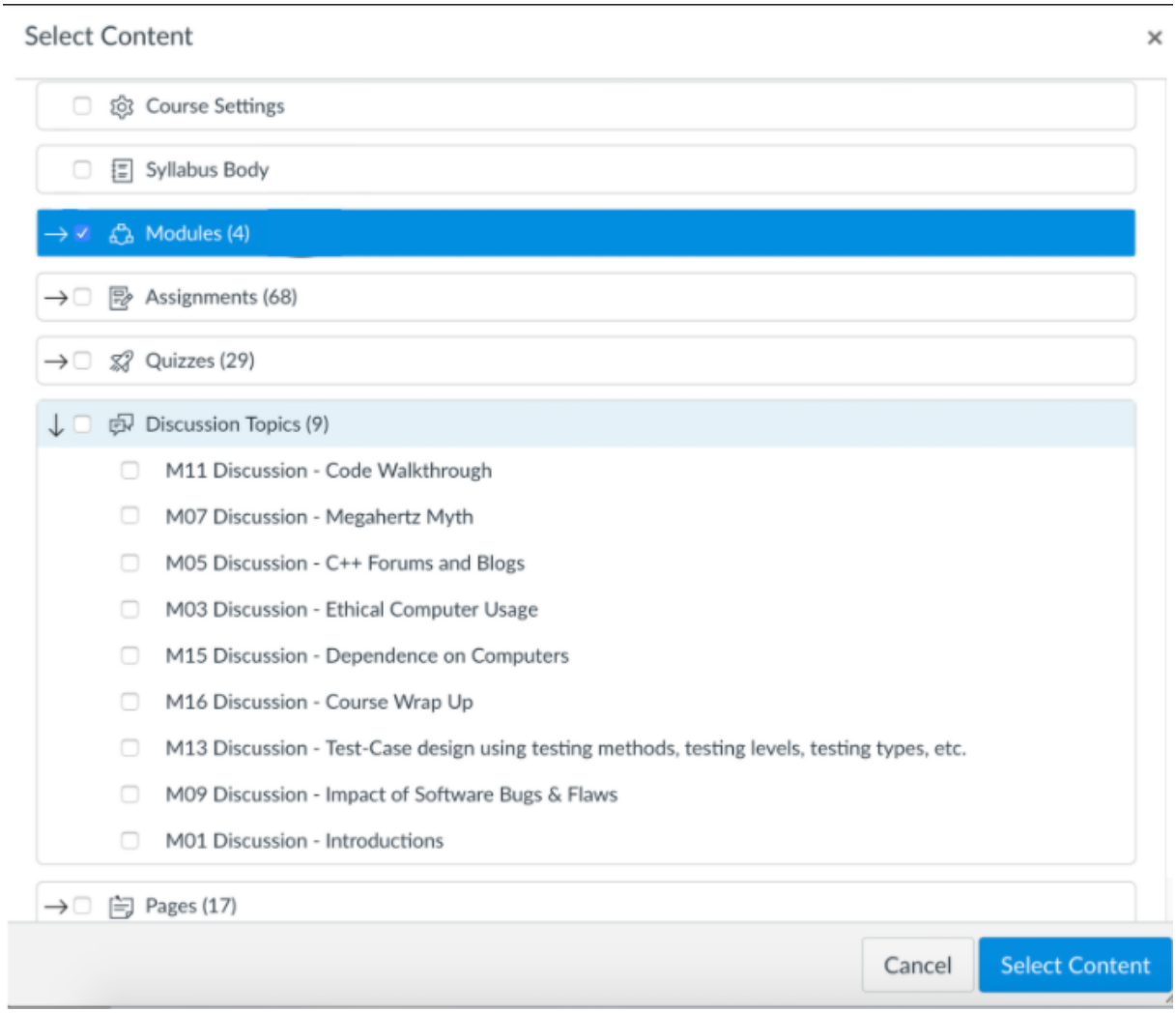

Figure 2.4: Selecting content to import from an existing course on Canvas LMS

If instead of a direct import from an existing course, one requires to import a local file, the system accepts various types of files as seen in Figure 2.5. SCORM is the technical standard for many e-learning content. The platform is SCORM compliant and if enabled, it will accept SCORM zip files which is a convenient feature allowing the creation of content on another platform and move content cross-platforms (e.g. move an assignment from Moodle to Canvas).

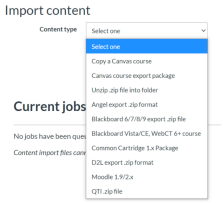

Figure 2.5: Selecting content type when importing content

Canvas Commons

Additionally, Canvas provides user access to a shared learning repository known as Canvas Commons (Figure 2.6). This is a platform which allows the sharing of courses and specific learning contents with all other Canvas users across the globe as shown in Figure 2.7.

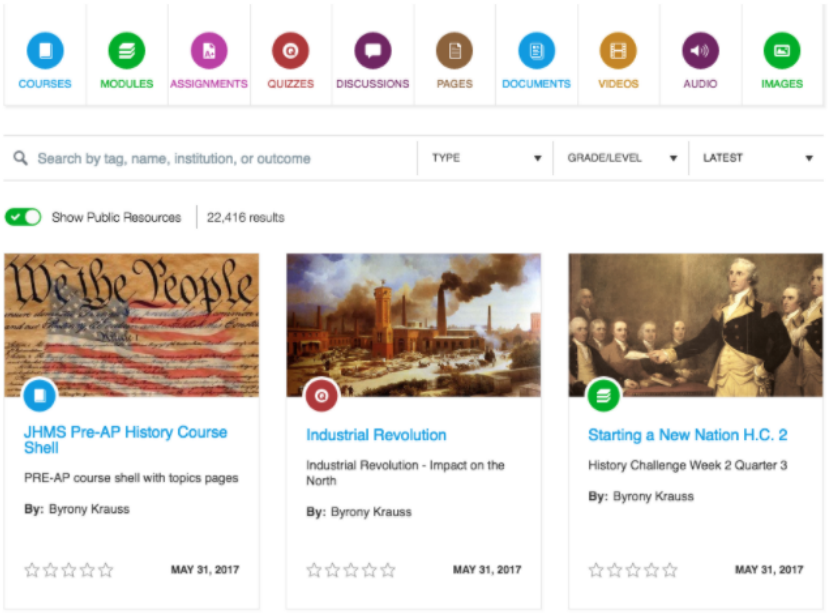

Figure 2.6: Canvas Commons homepage

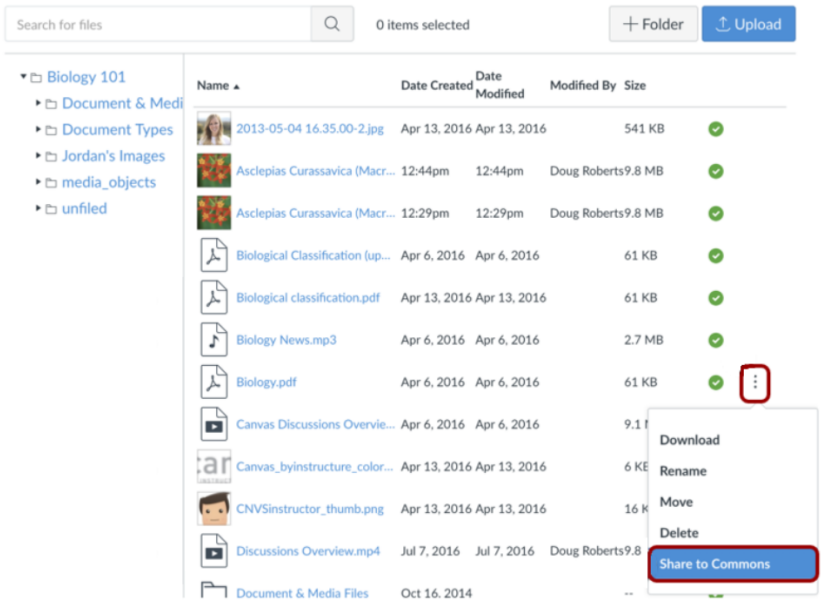

Figure 2.7: Canvas allows sharing of course content to Canvas Commons

2.2.2 Blackboard Learn

Blackboard Learn
(https://www.blackboard.com/teaching-learning/learning-management
/blackboard-learn) is "an application for online teaching, learning, community building, and knowledge sharing". It had been the most popular Learning Management System for 20 years in the US until the rise of Canvas overtook it in 2018.

Blackboard Learn focuses on student achievement and emphasises openness and flexibility. They aim to be open to integration and extension, acknowledging that Learn is "just one part of (the) educational ecosystem". Learn designs its platform strives for flexibility in order to adapt to the different needs of users whilst ensuring continuity.

Similar to Canvas, Learn provides numerous ways to reuse learning content on the platform where one can copy an entire course or parts of the course content in the platform, import courses from local packages as well as exporting courses. For copying a course, as shown in Figure 2.8, Learn provides three ways to copy where users can copy all or selected course materials from an existing course into a new course, into an existing course or an exact copy of the course can be made.

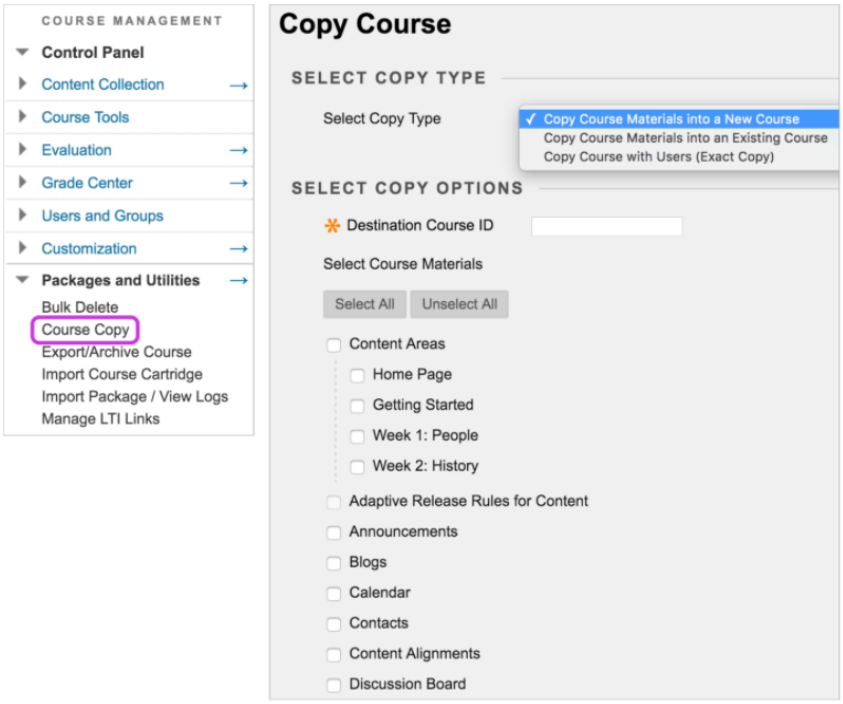

Figure 2.8: Copying a course on Blackboard Learn

The platform also allows users to import course packages from a local machine as shown in Figure 2.9. Learn supports a common cartridge format for course packages which provides convenience when moving content across learning Management Systems. As compared to Canvas which is SCORM compliant, common cartridges allow the package of a wider set of resources such as external discussion boards.

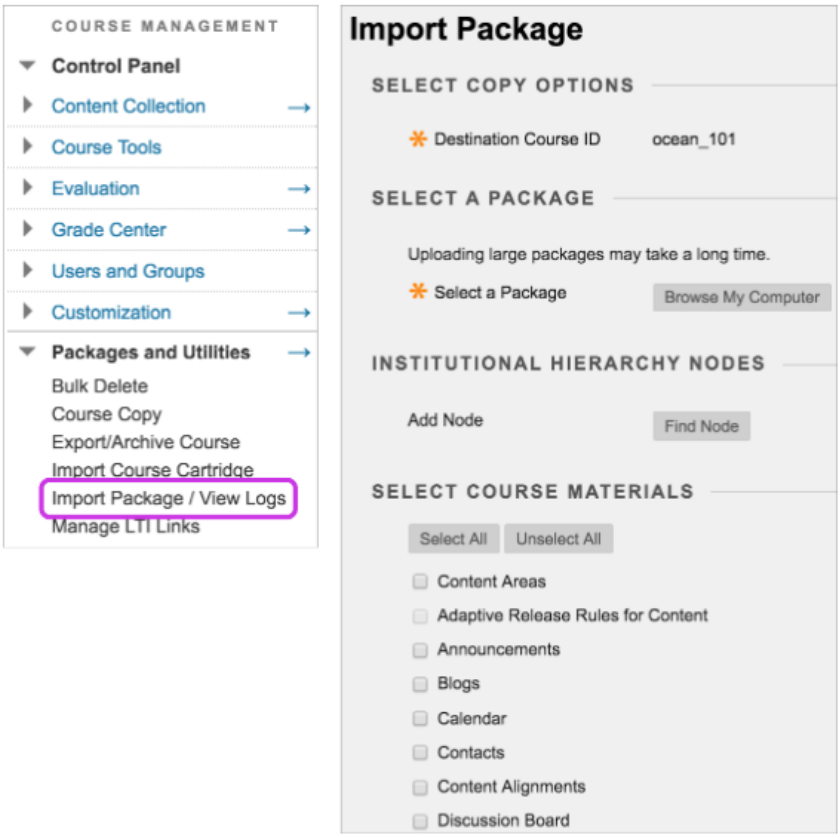

Figure 2.9: Importing a package onto Blackboard Learn

Learn supports exporting content as a ZIP file which can be imported into another course. However, the type of content which can be exported is limited to purely the course content without any user and user interactions data such as discussions.

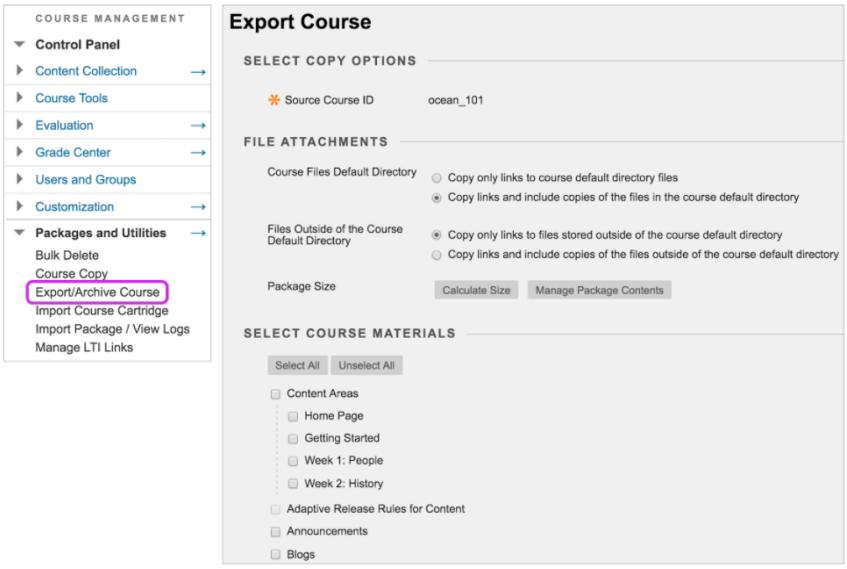

Figure 2.10: Exporting a course or parts of a course on Blackboard Learn

Additionally, a "Check Course Links" feature is provided on the system which allows the verification of the validity of all the links in the contents of a course. This is especially useful when courses are created from a combination of importing, copying and creating new content to ensure all items are linked together as expected.

2.2.3 Moodle

Moodle (https://moodle.org/) is currently the world's most popular learning management system. It is an open-source learning platform aimed at creating a personalised learning environment via a single integrated system with support for external tools.

Moodle strives to develop "a powerful set of learner-centric tools and collaborative learning environments that empower both teaching and learning." Similar to the other systems, it focuses on being highly flexible and fully customisable through being open-source and having a "modular set up and interoperable design".

Moodle allows the reuse of an entire course or a part of the content of a course. This is achieved by what Moodle identifies as a backup and restore process.

You can backup a particular activity of a course (Figure 2.11) or an entire course (Figure 2.12). These backup files (Figure 2.13) on the system can be restored or be downloaded. Much like all examples so far, Moodle also supports restoring resources by importing local files (Figure 2.14) onto the system. It is SCORM compliant.

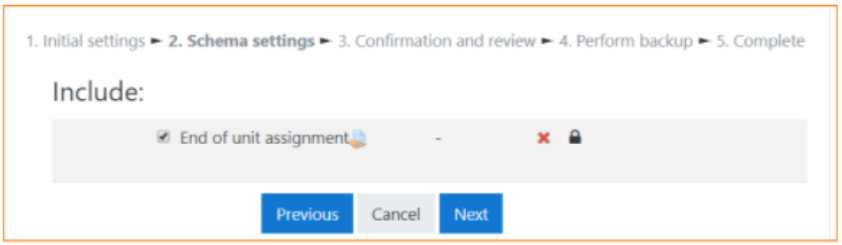

Figure 2.11: Backing up a particular activity on Moodle

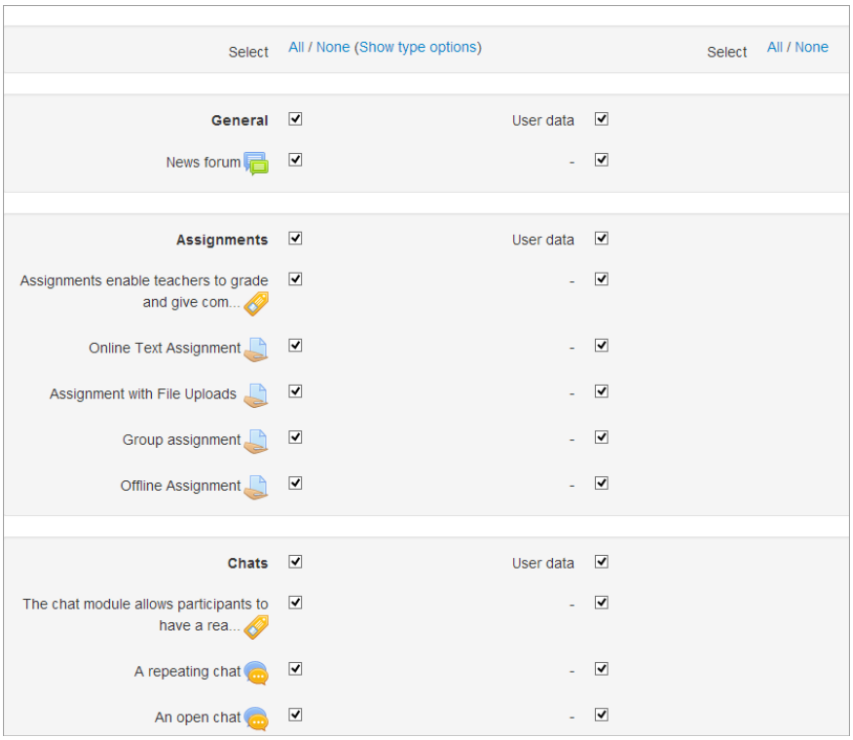

Figure 2.12: Backing up a course on Moodle

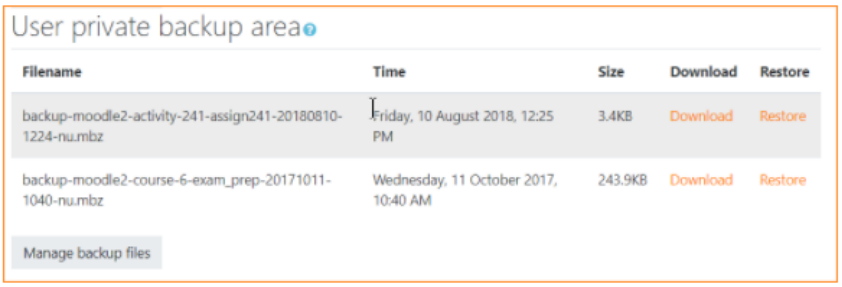

Figure 2.13: Back ups stored on Moodle

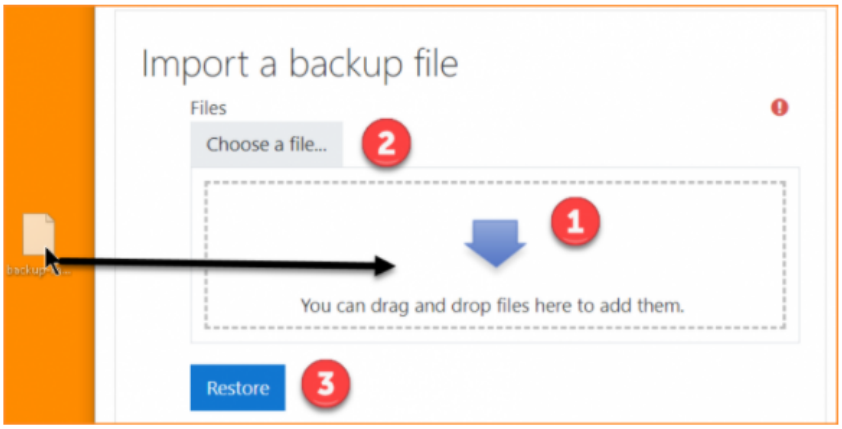

Figure 2.14: Importing files into Moodle

2.2.4 Desire2Learn Brightspace

Desire2Learn (D2L) Brightspace (https://www.d2l.com/en-apac/higher-education/) is a LTI-standard (Learning Tools Interoperability) compliant learning management system which integrates external tools and services to provide a centralised, convenient platform. The platform focuses on students' learning experience by its attempts to provide a different experience for everyone. Its philosophy is to design a product which is easy, flexible and smart.

In terms of being flexible, Brightspace is not only emphasising on a personalised student experience but also, customisable way of teaching, support in numerous learning models (online/blended approach) as well as in general having the ability to make changes in the system in a flexible way.

There are a few ways in which Brightspace demonstrates the reuse of content in its features;

- Reusing components from a previous offering of a course
- Reusing components by importing local files
- Reusing items in specific learning content/activities
- Reusing questions in quizzes and surveys through user forming their own Question Library
- Reusing videos that have been created in the past on the platform

The ability to reuse components of a course from previous offerings and by importing from files is quite similar to many other learning management systems.

2.2.5 Sakai

Sakai (https://www.sakailms.org/) is another learning management system allowing; Communication and Collaboration Grading and Assessment Content Development and Delivery Course and System Management Community Contributed Tools External App Integrations By being open-source, Sakai hopes to provide the flexibility for institutions to configure and customise the system according to their needs.

In Sakai, created content can be reused in several ways depending on the intended purpose. If a user would like to create a new course using some of the content from a previous course, the option is provided when the user creates the new course as shown in Figure 2.15. They are given the option of selecting which course to copy from and what specific content should be copied over (Figure 2.16).

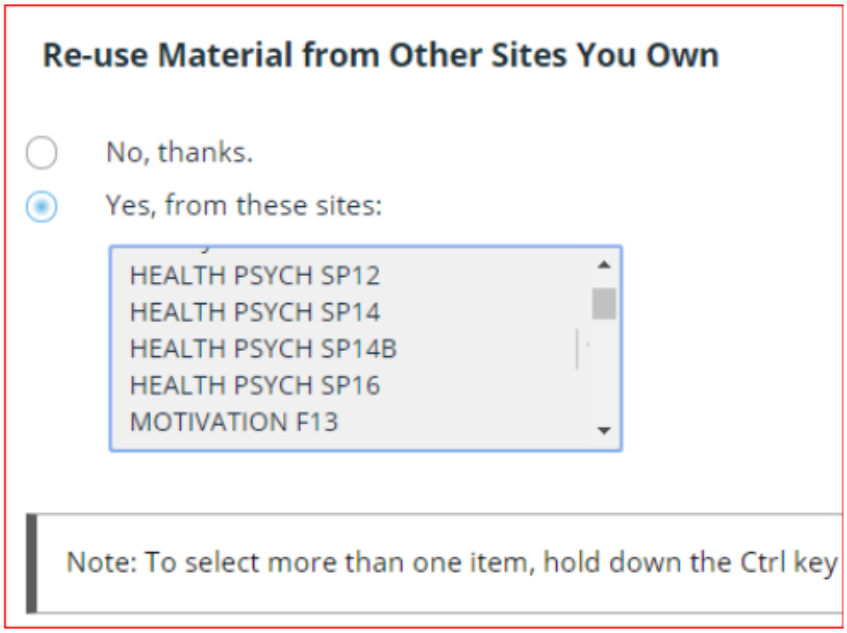

Figure 2.15: Prompt to reuse content when creating new course on Sakai

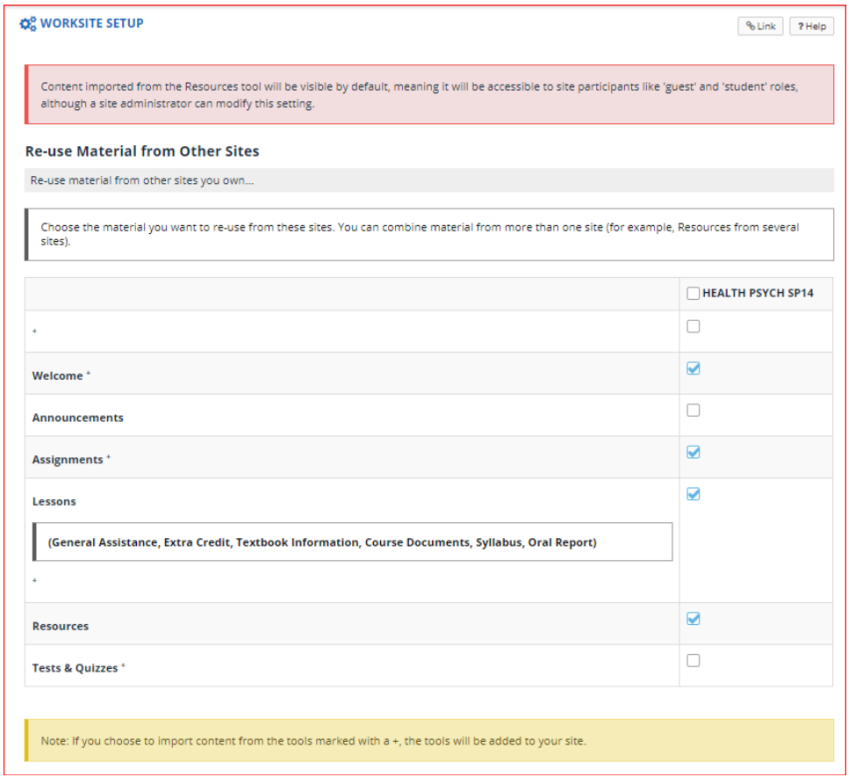

Figure 2.16: Selecting existing content from a course to copy to a new course

When a user would like to add more content to an existing course, they are given the option to import from another existing course.

Just like other learning management systems, it is also possible to export and import files containing learning content. An additional way to share and reuse content on Sakai, is through course sites which have added integrations with third party tools. Course-related content which is stored in the third party tool will be shared across multiple courses. For example, adding a Media Gallery tool to a course site on Sakai will mean that any content in the Media Gallery will be visible in a new course site which integrates the same Media Gallery.

2.2.6 WebCMS3

WebCMS3 (https://webcms3.cse.unsw.edu.au/) is a web-based course management system developed and used in the School of Computer Science and Engineering at the University of New South Wales (UNSW).

WebCMS3 offers a Course Cloning feature which allows you to select an existing course and the components in which a you would like to make a copy of. The example as shown in Figure 2.17, is a user trying to create a new course from cloning "COMP1927 15s2" and is given a selection of Menu, Course Outline, Resources, Group Types, Polls and Quizzes which they can clone for the course.

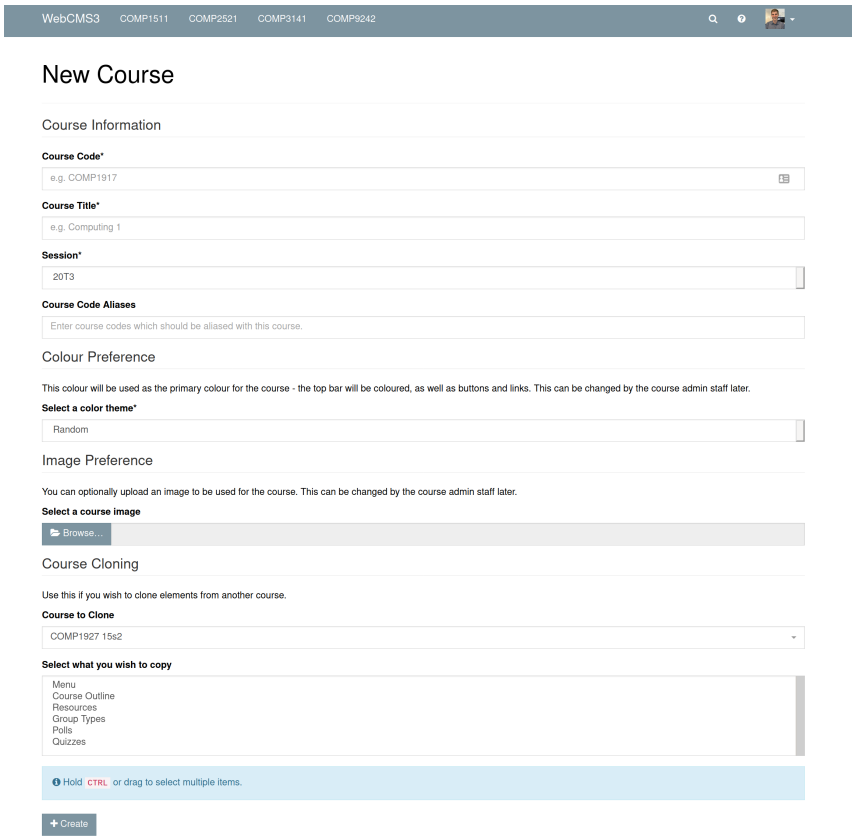

Figure 2.17: Creating a new course on WebCMS3

Another way in which WebCMS3 supports the reuse of content is allowing the reuse of questions from quizzes created on the platform by having a "Import an Existing Question" option. This allows users to search through the quizzes and clone questions in particular quizzes in any offering of a course as shown in Figure 2.18.

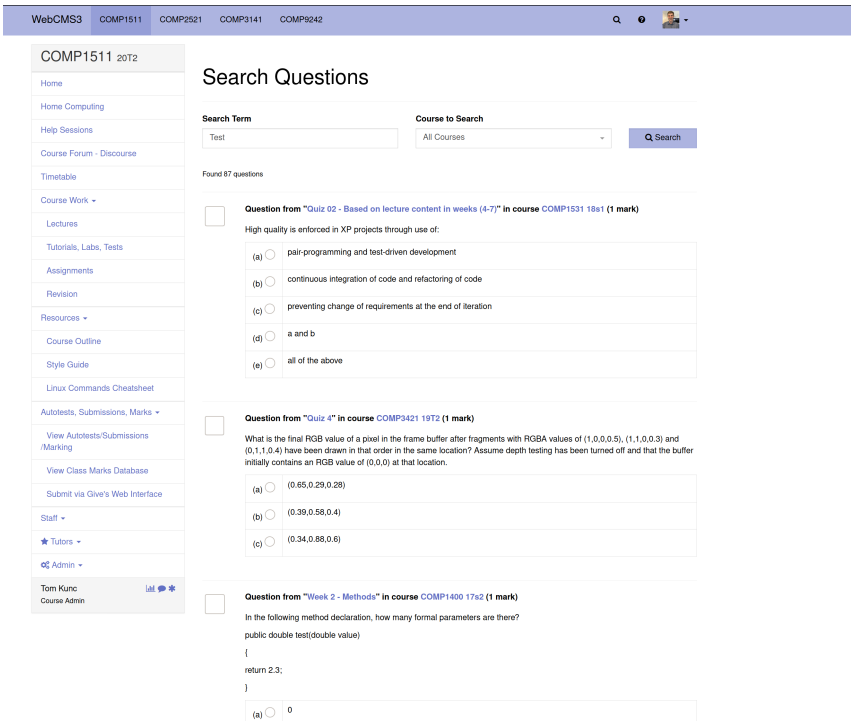

Figure 2.18: Creating a new course on WebCMS3

2.2.7 Authoring Tools

Authoring tools facilitate the creation of digital content such as documents, presentation slides and videos. In the context of e-learning, these are tools used to create a variety of education resources and can output into various formats with many being technical standards such as SCORM.

Many of the existing learning management systems mentioned have built-in authoring tools allowing the creation of content specifically for the courses on the system. An example of this is that many systems mentioned have the ability to create a quiz on the platform. These tools also provide its own level of reusability specific to the type of content being created as shown in many aforementioned examples such as the ability to reuse specific questions when creating a new quiz.

2.2.8 Analysis of Reusability

Many Learning Management Systems put a great focus on some level of flexibility in their philosophy. As it can be seen from the examples, in terms of flexibility in reusing content, the way in which the system addresses this is quite similar in that they use a standard process of being able to import and export packages to reuse an entire course or specific parts of a course despite some variations.

Now there are some issues with this existing solution. For example, if there was another course shared to Course Convenor A made by Course Convenor B, Course Convenor A is less likely to reuse the content as they may not know how and whether it is suitable to reuse any parts of it. There is no information as to how all the content within the course relate to each other without having to go through all the content manually.

There is no standardised structure for the knowledge and content being delivered to encourage reusability. Additionally, from all the examples aforementioned, most do not provide a centralised repository to maximise the reuse of content through sharing them so it is often limited to specific individuals.

2.2.9 Charles Sturt University Engineering Topic Tree

The Charles Sturt Engineering Topic Tree aims to remove semester-long subjects by introducing a topic tree structure which consists of interconnecting fine-grained topics that are "bite-size pieces of study" that are generally 3-hours long. As a student who studies using this topic tree, they can easily identify the prerequisites for a topic through the branches and the pathway to take in order to learn a particular topic. The student will follow and complete branches of topics to hit certain milestones. For example, "completion of (the) first 240 topics (in the tree) will ensure (that a student is) ready for work as a cadet engineer once (they are) on placement". By using this topic tree structure, it ensures that the learning for students is relevant, on time and personalised. The Figure2.19 shows what a part of the topic tree looks like. 2.19.

Figure 2.19: Charles Sturt Topic Tree

Chapter 3

Project Approach

The Meta Learning Management System aims to allow academics and course convenors the ability to easily share, repurpose and reuse digital assets and contents for different courses and course offerings. This is achieved by careful design of the standardised structure to represent learning content on the system as well as the general features provided by the system.

Specifically, the system allows the easy creation and storage of learning content which can be exported to be used or reused by a course or course offering of any format; online, in person or hybrid run on an existing learning management systems.

3.1 Definitions

Before delving into more details about the system, some terms need to be defined to establish a common understanding on some concepts.

3.1.1 Topic

A **Topic** is defined as the basic building block of a course which consists of learning materials. An example of this is linked list a concept that often appears in an Introductory C programming

course.

Learning Material

Learning Materials are any digital assets which facilitate student learning such as lecture videos, assignments and quizzes. Specifically, for this thesis, the types of Learning Materials include:

- Page
- Image
- Audio
- Video
- Document
- Quiz

The above types of Learning Materials have been carefully selected, inspired by an existing Learning Management System, Canvas. Most learning content can be represented by one of the above types. For example, a lecture can be delivered via a video, tutorial or laboratory exercises can be explained within a PDF document or a Markdown page.

3.1.2 Topic Group

A collection of Topics form a **Topic Group**. For example, C programming may be a Topic Group formed by Topics including Structs, Pointers and Linked List.

One Topic can only belong to one Topic Group.

Additionally, it is important to highlight the difference between a Topic Group and a **Course** which is a term commonly used in many higher education institutions. Courses are generally formed by adding content into a given time frame, whereas Topic Groups formed by Topics are

purely based on the content and decided by subject-matter experts without any limitation or considerations of time.

A more concrete example to demonstrate the difference between a Topic Group and a Course is that it is possible to have an "Introduction to Computing" Course which involves both C Programming and some content on Ethics in Computing, where content from C Programming and Ethics in Computing belong to two separate Topic Groups.

3.1.3 Discipline

Multiple Topic Groups can come together to form a **Discipline**. For example, Computer Science and Engineering can be a Discipline.

One Topic Group can only belong in one Discipline.

3.2 Standardised Structure of Learning Content

3.2.1 Topic Network Graph

The fine-grained Topics lay the foundation for the designed structure where each Topic is a node within a directed network graph.

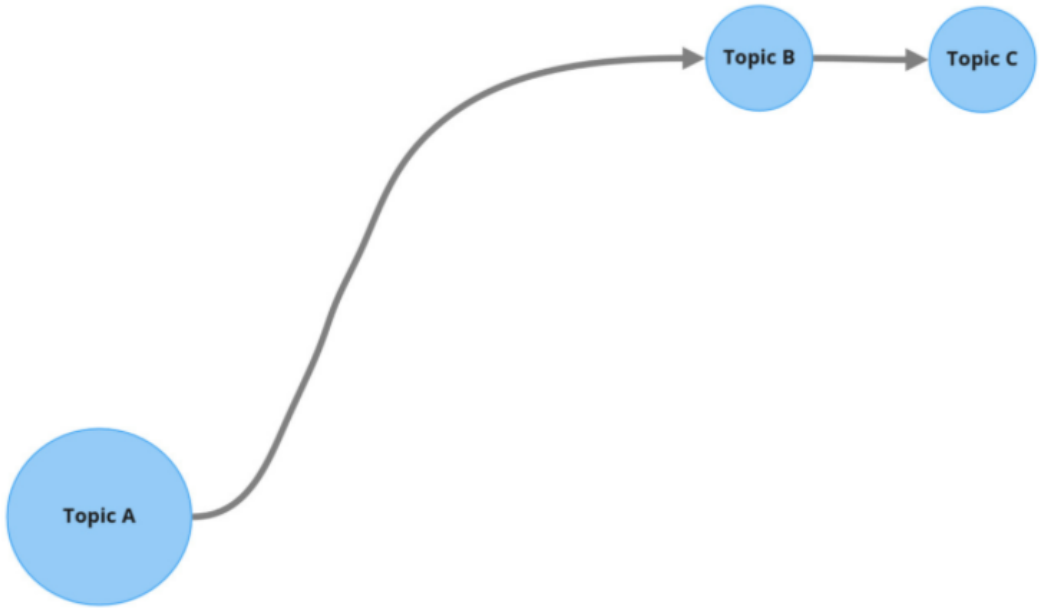

Figure 3.1: Example of Topic Nodes

The directed edges in between the nodes highlights the prerequisite relationships between Topics where if Topic A has a directed edge to Topic B, then Topic A is a prerequisite for Topic B where learnings from Topic A is assumed when going through Topic B. (Shown in Figure 3.2)

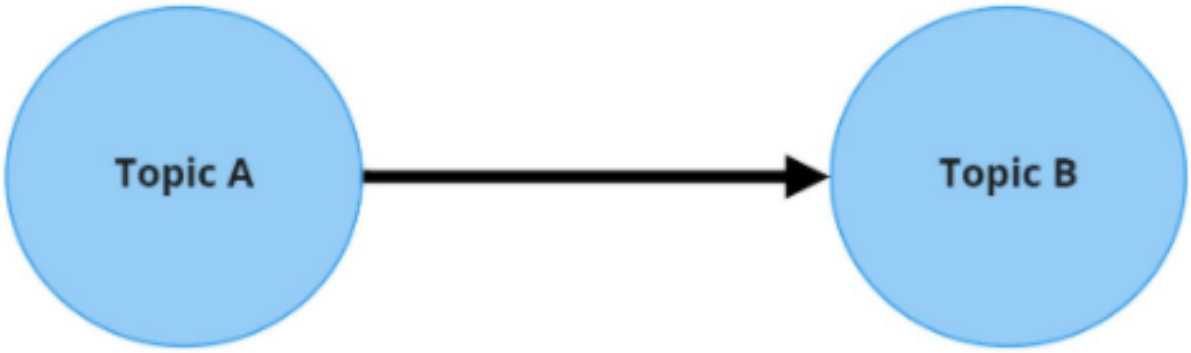

Figure 3.2: Topic A is a prerequisite for Topic B

A Topic can be a prerequisite for multiple other Topics and a Topic can have multiple Topic

prerequisites.

A specific example for a subset of topics in the context of C programming is shown. In order to learn linked lists, we have some prerequisite knowledge on struct, pointers and memory allocation. But in order to learn Pointers and Structs, we need to have knowledge on Variables.

3.2.2 Topic Node

Within each Topic node, Learning Materials are structured in a 4 stage process (in the following listed order);

1. Preparation - Learning Materials designed to introduce and prepare students for the core content of the Topic belong in this stage (e.g. articles for students to preread to prepare for learning the Topic)
2. Content - Learning Materials that deliver the core content for the Topic belong in this stage (e.g. lecture videos)
3. Practice - Learning Materials that provide students with more practical experiences on the core content learnt belong in this stage (e.g. practical lab exercises, tutorial questions)
4. Assessment - Learning Materials used to determine the level of skills and understanding of the Topic belong in this stage (e.g. quiz)

Visually, the stages are placed in a circular flowchart that revolves around the Topic to more closely model a student's learning process which is can be a continuous and iterative cycle rather than being linear.

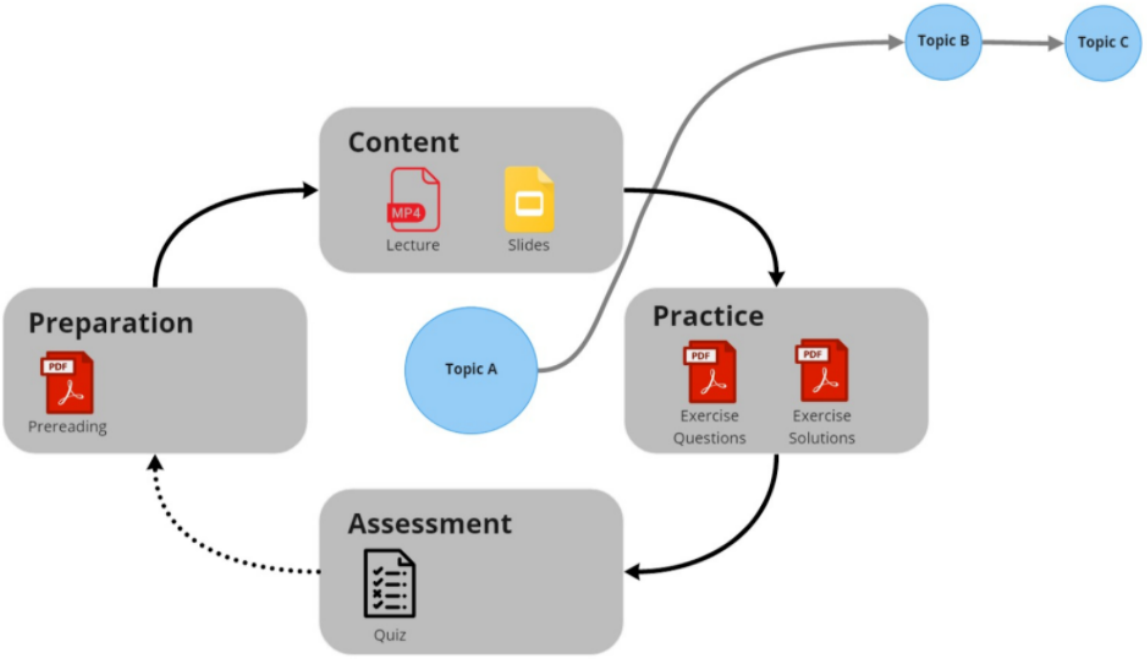

Figure 3.3: Visual Representation of a Topic

The diagram above (Figure 3.3) shows the visual representation of the structure inside a Topic node. Please note that the arrow connections between the stages simply describes the order and process of going through each stage and differs from the arrow connections between Topic nodes that describe prerequisite relationships.

The 4 stage process has been inspired by and summarised from extracting commonality within existing learning models as many existing models demonstrate similarities in their portrayal of the learning process. The following diagram provides an example of an existing learning models (from the UNSW's website about learning processes). (Figure 3.4)

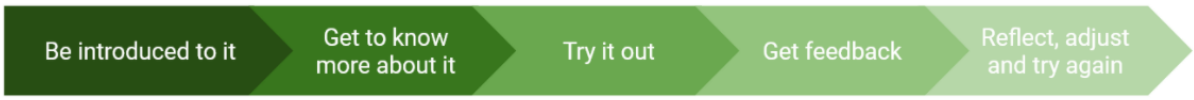

Figure 3.4: The Learning Process Suggested by an Existing Model

3.2.3 Topic Group Node

Topic Group nodes introduce a second dimension to the Topic Network Graph Structure formed by clusters of Topic nodes. The connections between Topic Group nodes are derived from the prerequisite relationships of Topic nodes within the clusters as shown in the following figure.

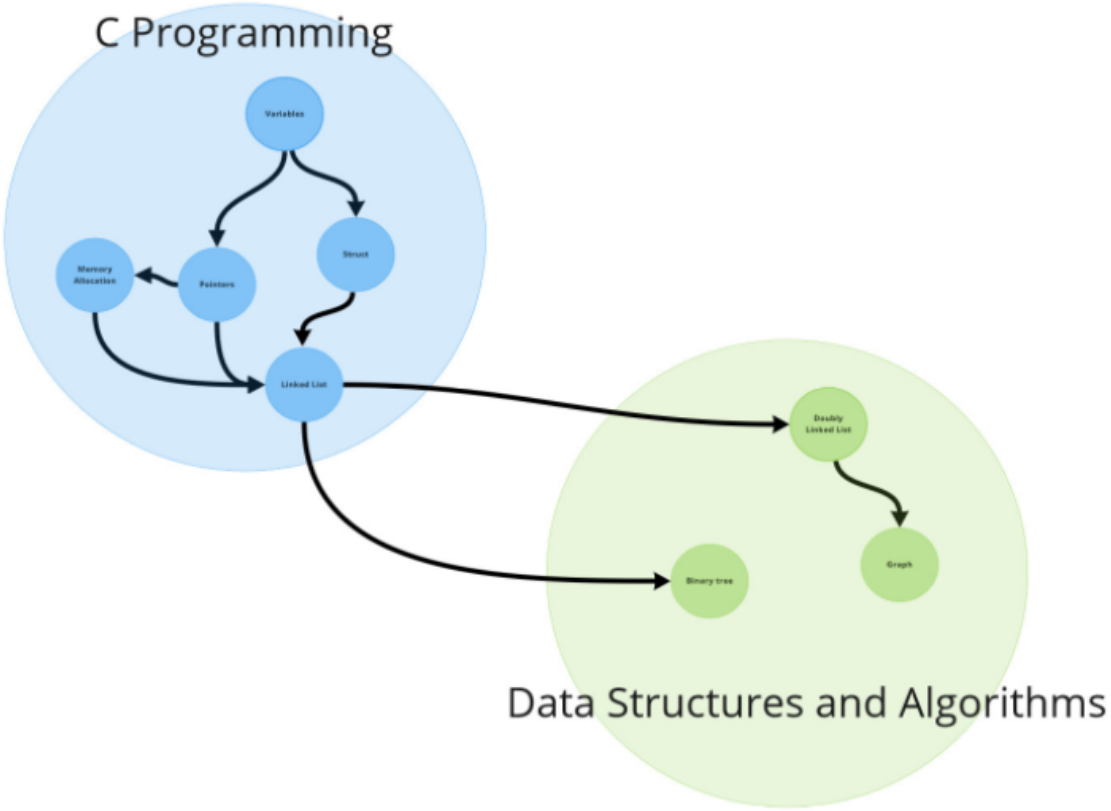

Figure 3.5: Example of Topic Group Nodes

3.2.4 Discipline Network

Another layer is introduced with the notion of a Discipline. There can be multiple networks of Topic Group nodes where each network consists of learning content from a Discipline.

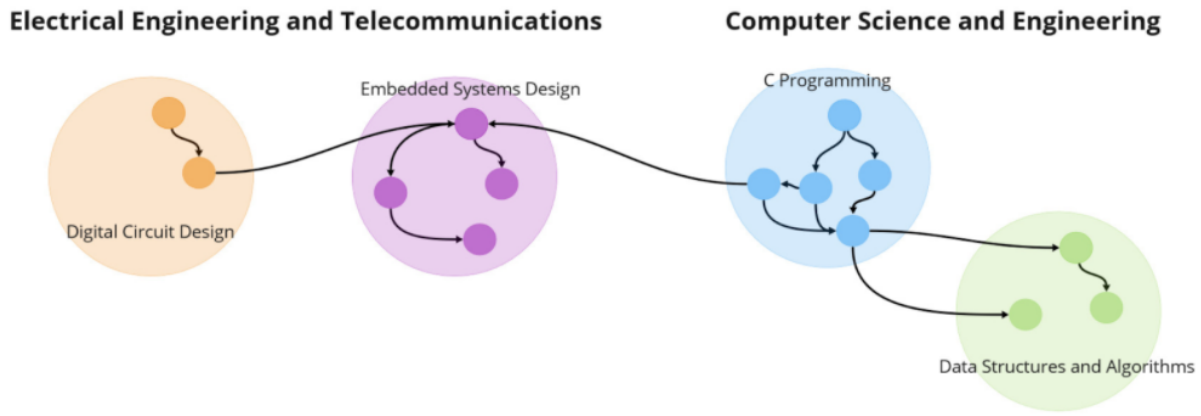

Figure 3.6: Example of Topic Group Nodes

3.3 Difficulties in Modelling Knowledge

There were considerations of numerous ideas and many difficulties were encountered during the process of creating the structure explained in the section above. Some of the main questions where were brought to light through the process of modelling the structure of content include (some still remain unanswered):

- Should the overall structure be a graph or a tree? - Based on existing research in Chapter 2, Charles Sturt University models learning content based on the structure of a tree. Questions were raise during the thesis whether the Meta LMS would be most appropriate being modelled as a tree or a graph. Portraying knowledge as a Graph was decided upon due to the flexibility of the graph structure and limitations in the structure of a tree where if a particular path is followed within a tree, it is difficult to "change paths" to lead into different directions.
- What is a Topic? - This has been a very difficult question to answer. In the early stages of this thesis, there were considerations in defining the notion of a Topic with time. However, by creating a Meta LMS, we are attempting to abstract away from concept of courses which is what is believed to be associated with the notion of time (since courses are created around a given time frame). Ultimately, a Topic had been defined as a "basic building block of a

course" to suggest that it is an "undividable chunk" of learning content. This definition is not perfect and has its limitations. For example, how granular do learning content have to be to be considered as undividable? Or can learning content ever be undividable? For the scope of this thesis, we have left these questions unanswered and attempted to achieve somewhat of a common understanding in what a Topic is by providing a definition and examples.

- What about the depth of a Topic? - In this thesis we have a standard definition of Topic and duplication of Topic simply refers to two Topics having the same or perhaps similar Topic title. However, it is possible that two versions of Learning Materials cover the same Topic to a different level of depth or detail. How should this be modelled?
- What is the relationship between a Topic and a course? - Multiple Topics can come together to form a course but what determines which Topics go into what course? In the initial stages of the thesis, the understanding was that a collection of Topics that have a common "theme" must become a course. However, it was later recognise that when creating courses there are many other external factors such as time which become involved. So the idea of a Topic Group was introduce to represent a collection of Topics which is formed purely based on the learning content involved in each Topic independent of external factors such as time.

3.4 Functional Requirements

The following section will specify the final system functional requirements for the Meta Learning Management System.

Conceptually, there are two main stakeholders, specifically:

- **Content Creator (i.e. Academic/Subject-Matter Expert)** who creates and modifies Learning Materials that populates the Meta Learning Management System.
- **Course Consumer (i.e. Course Convenor)** who consumes the Learning Materials on the Meta Learning Management System by using it in a course they create

However, in the functional requirements, both stakeholders will be collectively referred to as a **User** to eliminate confusions with the idea of accounts as both stakeholders change the same features and permission on the system. The final requirements do not include any account management or administrative features, due to reasons justified in Section 3.0.4.

The requirements have been decided upon based on the background research conducted. They have been modified and made more specific as further understanding about the thesis topic was developed throughout the execution process.

The requirements are shown in the form of User Stories following the Connextra template. They were prioritised based on the MoSCoW method to ensure that it was clear which requirements would be implemented first and that considerable progress is made throughout the thesis.

- [Must Have] - These outline the bare minimum required for a functional Meta Learning Management System.
- [Should Have] - These are requirements that extend the basic functionality of the Meta Learning Management System.
- [Could Have] - These are requirements that improve the user experience through bringing convenience and flexibility.
- [Won't Have] - These are extra requirements which are considerably more difficult to produce within the limited time-frame.

Requirements have been marked with one of the following statuses based on the acceptance criteria completed within the requirement:

- **Complete** if *all* acceptance criteria with priorities of [Must Have], [Should Have] or [Could Have] are completed.
- **Mostly Complete** if *more than half* of the acceptance criteria with priorities of [Must Have], [Should Have] or [Could Have] are completed.
- **Not Complete** if the requirement does not correspond to one of the above statuses.

The following outlines the list of requirements for the Meta Learning Management System.

3.4.1 Viewing

1. View All Topics

AS A	User
I WANT TO	View all Topics
SO THAT	I am informed about what Topics already exists in the system
Acceptance Criteria:	
✓1. The User can view both the Topics and their prerequisites [Must Have] displayed in the structure of a graph ✗2. The User can view the Topics and their prerequisites in a table format [Won't Have]	
Overall Priority	[Must Have]
Status	Complete

2. View All Details of a Topic

AS A	User
I WANT TO	View all details of a Topic
SO THAT	I am informed about what a particular Topic actually consists of
Acceptance Criteria:	
✓1. The User can view the description of the Topics [Must Have] ✓2. The User can view the prerequisites for the Topics [Must Have] ✗3. The User can view the amount of time that is required to go through [Won't Have] the Learning Materials in the Topic	
Overall Priority	[Must Have]
Status	Complete

3. View All Learning Materials of a Topic

AS A	User
I WANT TO	View Learning Materials for a Topic
SO THAT	I am informed about what content the Topic consists of
Acceptance Criteria:	
✓1. The User is shown all the Learning Materials for a Topic [Must Have] ✓2. The User can click on a particular Learning Material to view its actual content [Must Have]	
Overall Priority	[Must Have]
Status	Complete

4. View All Topic Groups

AS A	User
I WANT TO	View all Topic Groups
SO THAT	I am informed and can easily find the collection of Topics or a particular Topic I want looking for
Acceptance Criteria:	
✓1. The User can view Topic Group nodes in the graph [Could Have] ✓2. When a Topic Group node is clicked, the Topic nodes within the Group will be shown [Could Have]	
Overall Priority	[Could Have]
Status	Complete

5. View All Disciplines

AS A	User
I WANT TO	View all Disciplines
SO THAT	I am informed and can easily find the Discipline I am looking for and its relevant Topics/Topic Groups
Acceptance Criteria:	
✓1. The User can view all existing Disciplines via a dropdown on the Navigation bar [Could Have] ✓2. When a particular option is selected on the dropdown, the User is taken to the Network Graph [Could Have] which shows all Topic Groups/Topics for the Discipline	
Overall Priority	[Could Have]
Status	Complete

3.4.2 Navigating

1. Navigate through Graph

AS A	User
I WANT TO	Navigate through the graph
SO THAT	I can easily view the section of the graph I want to see
Acceptance Criteria:	
✓1. The User should be able to zoom in and zoom out of the graph using the scroll wheel of their mouse [Should Have] ✓2. The User should be able to drag the graph to move different sections of the graph to the center of their screen [Should Have]	
Overall Priority	[Should Have]
Status	Complete

2. Search by Keywords

AS A	User
I WANT TO	Search through the Topic Graph by keywords
SO THAT	The Topic or Learning Material which I am looking for can be located easily
Acceptance Criteria:	
✓1. The User can search for a Topic by Topic title [Must Have] ✓2. The User can search for Learning Materials by file name [Should Have] ✗3. The User can search for a Topic Group by Topic Group title [Could Have]	
Overall Priority	[Must Have]
Status	Mostly Complete

3.4.3 Creating/Editing

1. Create a New Topic

AS A	User
I WANT TO	Create a new Topic
SO THAT	New Learning Materials that do not belong into existing Topics can be added to this Topic
Acceptance Criteria:	
✓1. The User can enter the following details for the new Topic: - Topic title (required) [Must Have] - Short description for the Topic (required) [Must Have] - Topic Group the Topic belongs to (required) [Could Have] - Discipline the Topic belongs to (required) [Could Have] - Prerequisite(s) of the Topic (optional) [Must Have] ✓2. System will reject the new Topic if they are a duplicate of another Topic in the graph [Must Have] ✗3. System will suggest existing Topics if the new Topic to be added is similar to existing Topics in its Topics title [Should Have]	
Overall Priority	[Must Have]
Status	Mostly Complete

2. Edit Existing Topic

AS A	User
I WANT TO	Edit an Existing Topic
SO THAT	Information about an existing Topic can be updated
Acceptance Criteria:	
✓1. The User can edit the following details for an existing Topic: - Topic title [Must Have] - Short description for the Topic [Must Have] - Topic Group the Topic belongs to [Could Have] - Discipline the Topic belongs to [Could Have] - Prerequisite(s) of the Topic [Must Have] ✓2. System will reject the changes if the updated Topic title is the same as an existing Topic's title in the graph [Must Have] ✓3. System will reject the changes if the updated prerequisites for the Topic results in a cycle in the graph [Must Have]	
Overall Priority	[Must Have]
Status	Complete

3. Remove Existing Topic

AS A	User
I WANT TO	Remove an Existing Topic
SO THAT	Outdated or accidental addition of Topics do not remain in the system
Acceptance Criteria:	
✓1. The User can choose to remove a specific Topic in the system [Must Have] ✓2. When a Topic is removed, all of the Learning Materials for the Topic is also removed [Must Have]	
Overall Priority	[Must Have]
Status	Complete

4. Upload or Create Learning Materials

AS A	User
I WANT TO	Upload new Learning Materials
SO THAT	Topics will be populated with Learning Materials ready to be used and reused
Acceptance Criteria:	
✓1. The User can upload a file of the following types into a particular Topic: [Must Have] - image (PNG, JPG) - audio (MP3) - video (MP4) - document (PDF, Markdown)	
Overall Priority	[Must Have]
Status	Complete

AS A	User
I WANT TO	Create new Learning Materials
SO THAT	Topics will be populated with Learning Materials ready to be used and reused
Acceptance Criteria:	
✓1. The User can directly create and save a Markdown document on the system [Could Have] ✓2. The Markdown document should support: [Could Have] - displaying text - displaying images - code syntax highlighting ✗3. The User can directly create an interactive quiz and save it on the system [Won't Have]	
Overall Priority	[Could Have]
Status	Complete

5. Edit Existing Learning Materials

AS A	User
I WANT TO	Edit Existing Learning Materials
SO THAT	Updates can be made when Learning Materials are incorrect or become outdated
Acceptance Criteria:	
1. The User can directly make edits on the system for the following file types: ✓- document (Markdown) [Could Have] ✗- quizzes which were created on the system [Won't Have] ✗2. The User can reupload files for the following file types: [Could Have] - image (PNG, JPG) - audio (MP3) - video (MP4) - document (PDF)	
Overall Priority	[Could Have]
Status	Not Complete

6. Remove Existing Learning Materials

AS A	User
I WANT TO	Remove an existing Learning Material
SO THAT	Outdated or accidental additions of Learning Materials do not remain in the system
Acceptance Criteria:	
✓1. The User can choose to remove a specific Learning Material in a particular Topic by right clicking on the Learning Material to be removed [Must Have]	
Overall Priority	[Must Have]
Status	Complete

7. Create Multiple Versions of Topic's Learning Materials

AS A	User
I WANT TO	Create multiple versions of Learning Materials for a Topic
SO THAT	There can be different variations of Learning Materials for the same Topic to choose from when needed
Acceptance Criteria:	
✗1. The User can create a new version of the Topic within the Topic to allow the addition of alternative versions of Learning Materials that deliver the content to be added [Won't Have]	
Overall Priority	[Won't Have]
Status	Not Complete

3.4.4 Exporting

1. Download a Learning Material

AS A	User
I WANT TO	Download a particular Learning Material
SO THAT	A local backup of the Learning Material can be kept and viewed offline
Acceptance Criteria:	
✓1. The User can right click on a particular Learning Material and choose to download it to their local disk [Must Have]	
Overall Priority	[Must Have]
Status	Complete

2. Export a Topic

AS A	User
I WANT TO	Export a Topic
SO THAT	Data can be imported into an existing Learning Management System and/or a local backup of all details and Learning Materials relating to a particular Topic can be kept
Acceptance Criteria:	
✓1. The User can export a Topic as a ZIP file which contains all of its details (title, description, prerequisites) in a README markdown file as well as all the [Must Have] Learning Material files relating to the Topic ✓2. The User can export a Topic as a Common Cartridge package which contains all the Learning Materials relating to the Topic. [Could Have] ✓3. The Common Cartridge package can be imported into an existing Learning Management System which accepts this package type to be reused on the system. [Could Have]	
Overall Priority	[Must Have]
Status	Complete

3. Export a Topic Group

AS A	User
I WANT TO	Export a Topic Group
SO THAT	Data can be imported into an existing Learning Management System and/or a local backup of details and Learning Materials relating to all Topics within the Topics Group can be kept
Acceptance Criteria:	
✗1. The User can export a Topic Group as a ZIP file which contains all Learning Materials relating to all Topics within the Topic Group [Could Have] ✗2. Within the ZIP file, there should be a README markdown file which identifies the prerequisite relationships between Topics within the Topic Group [Could Have] ✗3. The User can export a Topic Group as a Common Cartridge package which contains all the Learning Materials relating to the Topic. [Could Have] ✗4. The Common Cartridge package can be imported into an existing Learning Management System which accepts this package type to be reused on the system. [Could Have] ✗5. When imported into an existing Learning Management System, the Common Cartridge package should allow the Learning Materials to retain its original structure in the system; Learning Materials are shown under the Topic they belong to and Topics should be displayed in an order which respects the prerequisite relationships between them [Could Have]	
Overall Priority	[Could Have]
Status	Not Complete

3.5 Changes from Initial Functional Requirements

As deeper understandings of the topic was developed throughout the thesis, adjustments were made to the initial requirements to focus on and prioritise demonstrating more features that support the overall goal of the thesis.

For example, requirements relating to Account Management and System Administration has been removed from the scope of this project and replaced with requirements relating to the notion of Topic Groups and Disciplines.

3.5.1 Considerations - Devising and Adjusting Requirements

Existing requirements have evolved to become more concrete with the growing understanding throughout thesis. This section discusses the thought process on finalising some of the behaviour of the system.

Ensuring the Absence of Duplication

To ensure that the system follows the aim of reducing duplication and encouraging reusability, when a Topic is added into the system, the system checks that no existing Topics has the same Topic title as the new Topic being added, otherwise, the new Topic should be rejected.

Complications due to Dependencies Between Topics

Complications arise in operations on the Topic Graph due to dependencies from prerequisite relationships between Topics. The following two operations required additional thought when designing its requirements;

- Removing an existing Topic
- Editing prerequisites of an existing Topic

Removing an Existing Topic

When considering the removal process of an existing Topic in the system, 4 different possible outcome had been devised as to what it means by removing a particular Topic. When a Topic is removed:

1. Remove just the Topic and its Learning Materials *leaving Topics which require this Topic as prerequisite with no prerequisites*
2. Remove the Topic and its Learning Materials *as well as all Topics and Learning Materials which require this Topic as a prerequisite*
3. Remove the Topic and its Learning Materials with existing Topics that require this Topic as prerequisite *update their prerequisite(s) to the prerequisite(s) of the Topic about to be removed*
4. *Prompt Users to update the prerequisites of every Topic requiring this Topic about to be removed* before the removal of the Topic and its Learning Materials is deemed successful

Deciding on an option from the above becomes a trade off between simplicity and flexibility of the system as well as questioning what would minimise User's confusions. In the final requirements, simplicity had been prioritised with the first option being chosen. It is believed this option achieves the right balance between simplicity and flexibility as it does not force the User to update prerequisites of every Topic which depend on this Topic to be removed but still allows the flexibility of doing so by editing the Topic later themselves.

Editing Prerequisites

When editing a Topic's prerequisites, restrictions had been added in how an User is allowed to edit a Topic's prerequisites; the updated prerequisite relationships cannot cause circular dependencies of any kind. If no restrictions were in place, it is possible for a cycle to be formed where for example Topic A is a prerequisite for Topic B, Topic B is a prerequisite for Topic C but Topic C is a prerequisite for Topic A. A Topic requiring a prerequisite to be itself would also be possible. (as shown in the following diagram) Conceptually, these types of circular dependencies are invalid and nonsensical; you cannot expect one to have knowledge about a certain Topic to eventually learn the Topic.

Navigation through a Large Topic Graph

A network of fine-grained Topics linked together by their prerequisite relationship becomes difficult to navigate through and use when the network grows. With Topics being defined as small, "basic building blocks" for courses, the network will easily become quite large and graph navigation becomes a serious issue. A few features of the system has been introduced to improve on the structure of the network and the navigation procedures as an attempt to reduce issues when a Topic Graph becomes larger.

Topic Group and Discipline

The notion of Topic Group and Discipline introduced a second dimension to the Topic Graph, allowing nodes to be grouped together and hence improving the organisation of the graph. As a result, the graph is more user-friendly to navigate through as a User can now navigate to different Disciplines, view Topic Groups and explore within a particular Topic Group they are looking for. In the initial requirements, there had been mentions of the notion of a "suggested course" instead of Topic Groups and Disciplines. This idea has now been eliminated due to the concept of a course often being associate with the notion of time as aforementioned in Section 3.1.2.

Search by Keywords

Another improvement on the navigation of the Topic Graph is the functionality of search, in the initial requirement, a User could only search for a Topic whereas the requirements now include both searched by Topic title as well as Learning Materials within each Topic to assist the navigation and exploration through the graph.

3.5.2 Non-Functional Requirements

The following specifies the properties in which the system should have:

1. Extensibility - The system should be open to extension and addition of new features and functionalities.
2. Performance - The system should have relatively short response time to different requests.

3. Security - System data should be stored in a secure way and only accessible by users with the right access permissions.

4. Data Integrity - The data in the system should be consistent throughout the system and its entire life-cycle.

Chapter 4

Project Execution

4.1 System Architecture and Technologies

This section outlines the system architecture and the technology stack of the implemented system. The technologies adopted in the system had changed throughout the thesis as more skills and experiences were gained during the process of implementation.

The system follows a three-tier architecture involving the presentation layer, logic layer and a data layer. The following diagram summarises the architecture of the system and the main technologies. The arrows represent the direction in which data flows. More details are provided in the following sections.

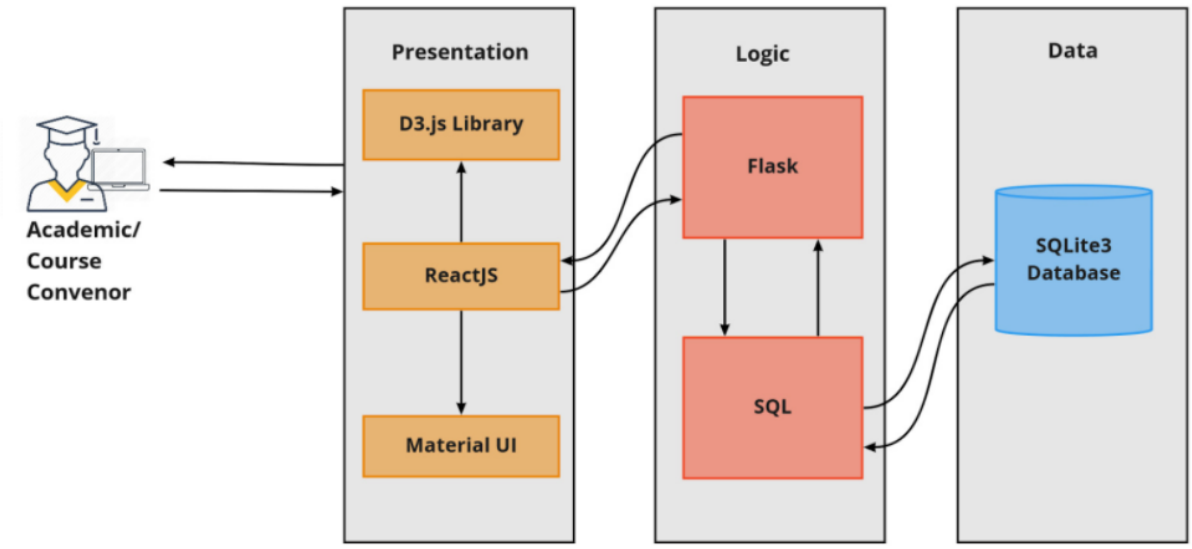

Figure 4.1: Software Architecture

4.1.1 Presentation Layer

The presentation layer is also known as the UI or view layer and it is the layer responsible for managing the direct interactions between the User and the system.

For this layer, the following technologies have been used:

- **ReactJS**, a front end library for building user interfaces. This library was chosen as part of the technology stack due to some previous and continuous experience with the library. Some alternatives which were considered were Angular and Vue.js, which were eventually eliminated due to the lack of experience and knowledge in regards to the two libraries.
- **JavaScript**, a programming language used in combination with the ReactJS library to enable interactivity on web pages. This was decided upon over TypeScript due to the need to produce a working prototype within a limited amount of time. TypeScript requires some additional setup and sufficient experiences working with strict typing on variables. However, it enforces better code quality which does benefit in the long term.
- **React Redux**, a library for managing a React application's global state. It is not an

essential part of the presentation layer. However it was adopted later in the project's implementation to allow for better and more convenient management of state across different components in the presentation layer. It is one of the most popular libraries for managing application state.

- **Material UI**, a React UI framework which is used to allow consistency in the aesthetics of the front end UI components. It is easy to use and one of the most popular UI frameworks for building React components.
- **D3.js**, a data visualisation library used in this project for producing an interactive SVG to represent a Topic Graph. After many other alternatives were experimented with including, React D3 Graph and Cyptoscape.js, this library was adopted later in the implementation process due to its flexibility in allowing a more customisation with the graph being built.
- **Material UI Dropzone**, a React UI component based on Material UI which provided a file uploading interface in the presentation layer. It was chosen due to its capabilities in allowing both uploads of a single file and multiple files at the same time as well as its ability to not only upload through clicks but also drag and drop.
- **React Markdown**, a component allowing the rendering and editing of Markdown documents on a web page. It supports the rendering of text, code as well as links and images.
- **React Syntax Highlighter**, a component allowing code syntax highlighting in the Markdown documents.
- **React File Previewer**, a React UI component allowing the preview of different file types (images and PDFs) on a web page.

4.1.2 Logic Layer

The logic layer acts as a connection between the presentation layer and the data layer. It is where the core logic about how data is created, stored or modified resides.

For the logic layer, the following technologies have been used:

- **Flask**, a micro web framework in Python used to build a RESTful API with the Flask-RESTPlus extension. This framework was chosen due to its light-weight nature for building a proof of concept system efficiently as well as having had past experiences with using the technology.
- **Python3**, a programming language used to construct the logic for creating, modifying data, error handling and other backend computations.
- **SQL**, a programming language used to communicate with relational databases to access, store, update and remove data.

4.1.3 Data Layer

The data layer concerns with the storage of data for the system.

The following technology has been used for this layer:

- **SQLite3**, a relational database management system. A relational database has been chosen due to past experiences working with it as well as its structured nature which cleanly organises the data. Specifically, SQLite3 is used as it is a lightweight system, suitable for this thesis project.

4.2 User Interface Design

The user interface has been adjusted numerous times throughout the thesis due to changes and addition of ideas. The following sections include wireframes with the interface designs. All wireframes shown are for illustration purpose only. The implemented interface of the system is detailed in Chapter 5.

4.2.1 Final Designs

Figure 4.2 shows the page Users see when they first access the system. As shown in the diagram, the graph structure described in an earlier section of this report is shown to the User where Topic nodes are displayed within Topic Group nodes.

A navigation bar appears at the top of the page. A dropdown allowing Users to select the Discipline in which they are looking at on the graph exists on the left hand side of the navigation bar. A search bar is shown next to the dropdown for Users to search for Topics or Learning Materials.

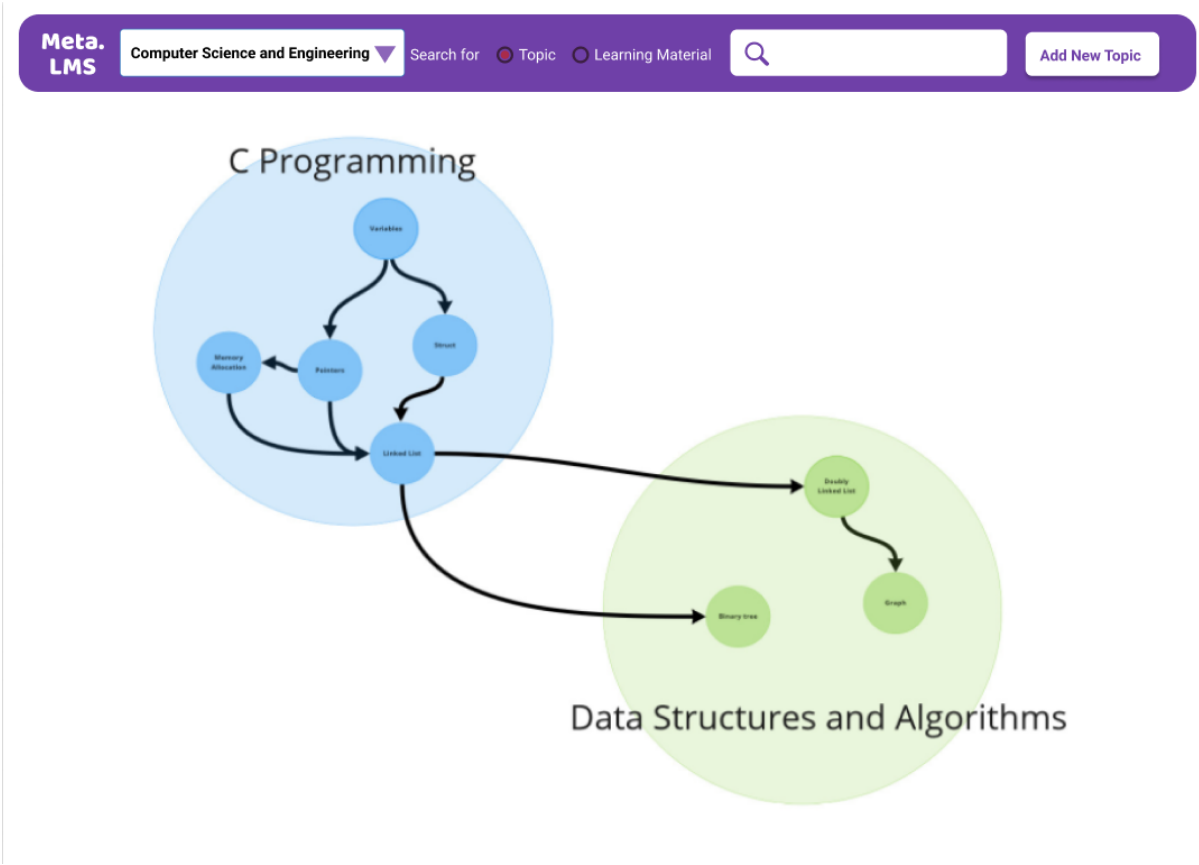

Figure 4.2: Final UI Design for Topic Graph

Conceptually, there is a flaw in the above design in the way in which Disciplines are represented. In this design, there exists the assumption that there will be no prerequisite relationships between Topics that belong to different Disciplines since only one Discipline can be shown on the page

at a time meaning dependencies between Disciplines cannot be depicted in the same way on the graph.

When clicking onto a Topic node, the details about the Topic can be seen in the structure discussed previously. Users can drag and drop Learning Materials from their local disk into each of the stages of the Topic. This standardised structure design prioritises simplicity over flexibility.

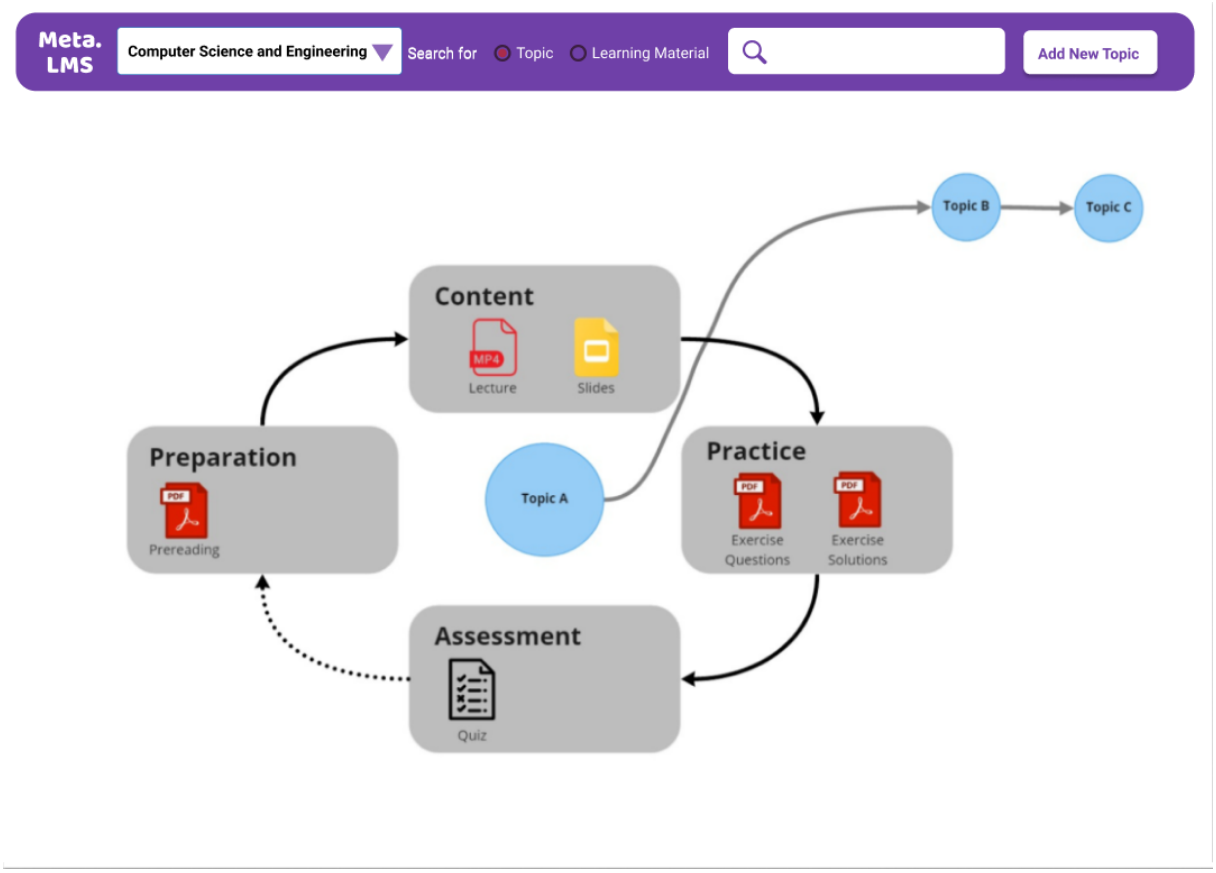

Figure 4.3: Final UI Design for Viewing Topic Details

4.2.2 Changes Compared to Initial Designs

The following image (Figure 4.4) shows the initial design of the Topic Graph. As it can be seen, Topics and prerequisites were incorporated into the design, but the notion of Topic Groups and Disciplines were not present in this draft.

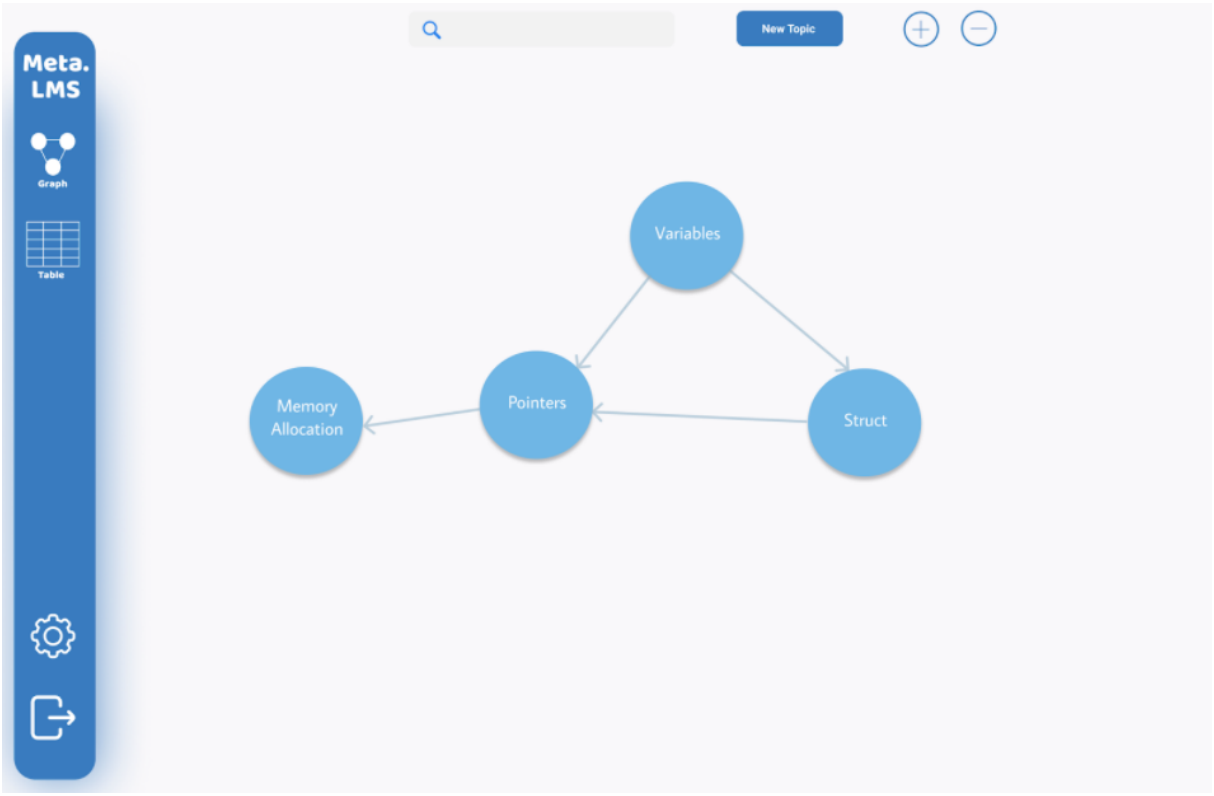

Figure 4.4: Initial UI Design for Topic Graph

When clicking on a Topic node to view the details of the Topic (Figure 4.5), a side bar slides out from the right hand side showing all details related to the Topic as well as the Learning Materials in a list. This original design was inspired by the existing Learning Management System, Canvas. Canvas prioritises the flexibility of its system to cater to various kinds of Users whereas as it could be seen in the final designs of this system, simplicity was ultimately prioritised, minimising learning curve of Users. This in turn improves efficiency of the processes, adhering to the initial goals.

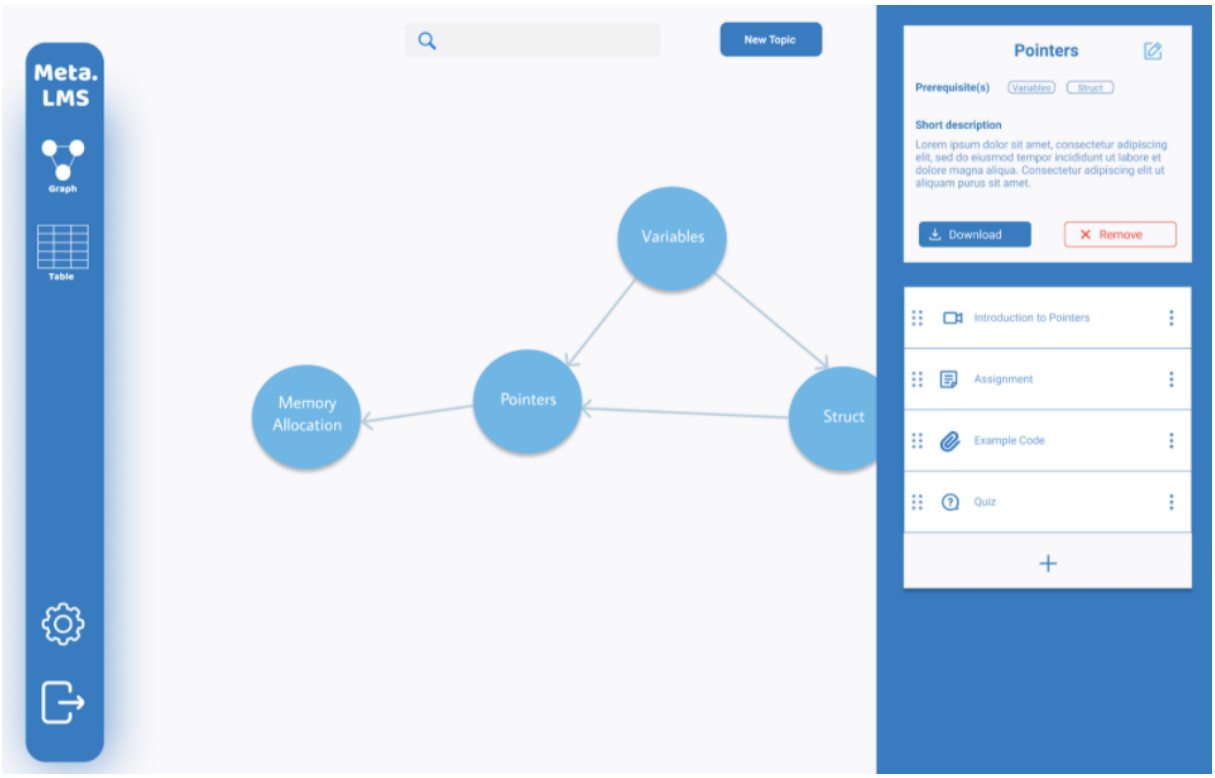

Figure 4.5: Initial UI Design for Viewing Topic Details

Furthermore, adding new Learning Materials to a Topic in this initial design, requires more clicking actions from the User. This is reduced in the final design as shown previously.

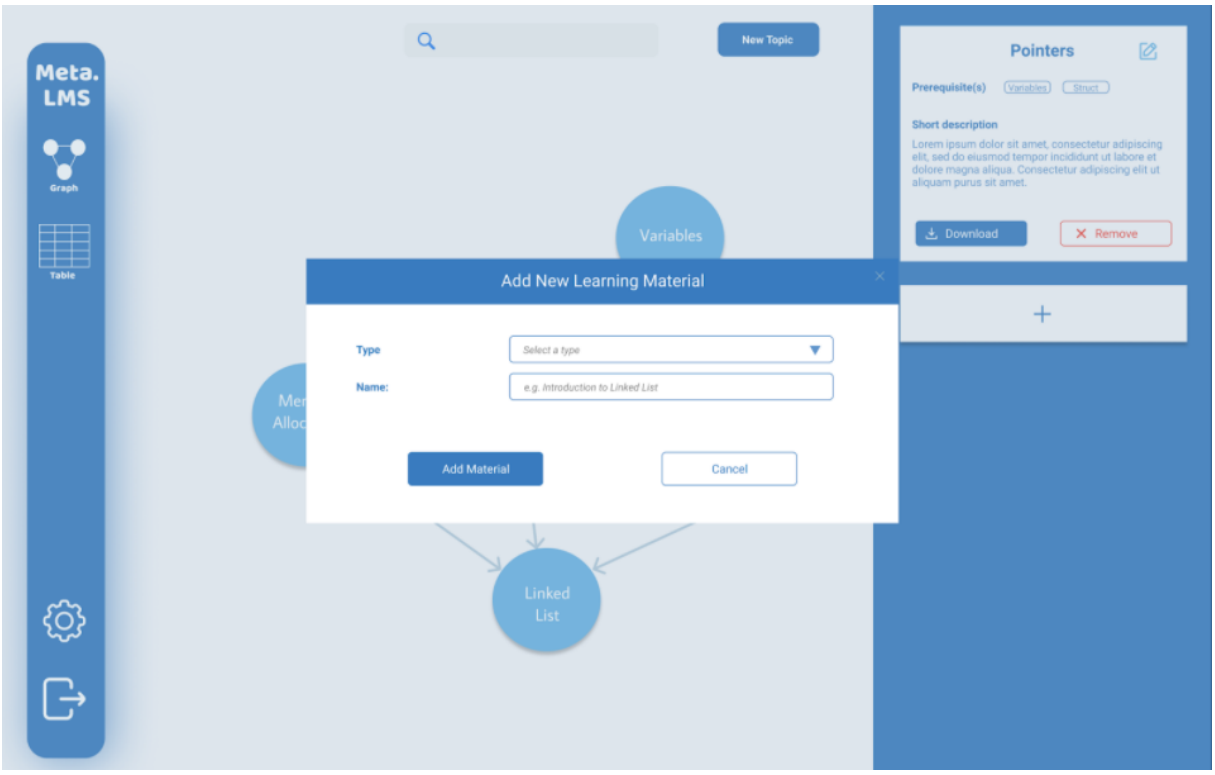

Figure 4.6: Initial UI Design for Adding New Learning Materials

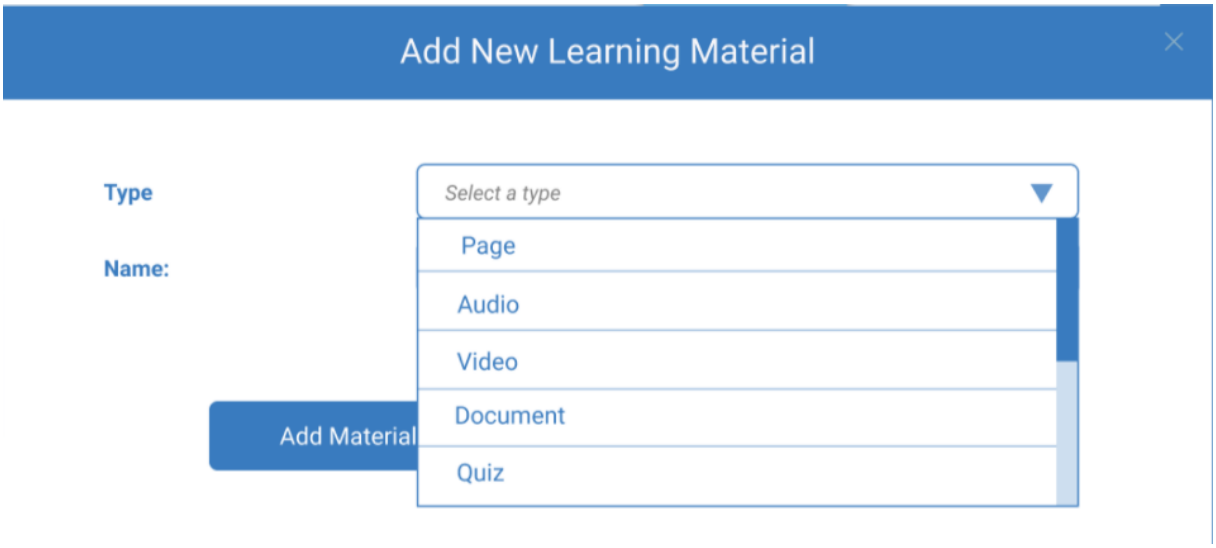

Figure 4.7: Initial UI Design for Selecting the Type of Learning Materials to Add

4.3 Application Programming Interface Design

The API endpoints of the backend of the system has been documented using Swagger Documentation. An overview of all the endpoints for the system has been shown in the following diagram.

The final design of the endpoints have been made to be more modular as opposed to an initial design where there were fewer endpoints but each endpoint performed many tasks. The changes was made due to realisation of a large amount of duplicate code where different endpoints performed similar functionalities with slight variations.

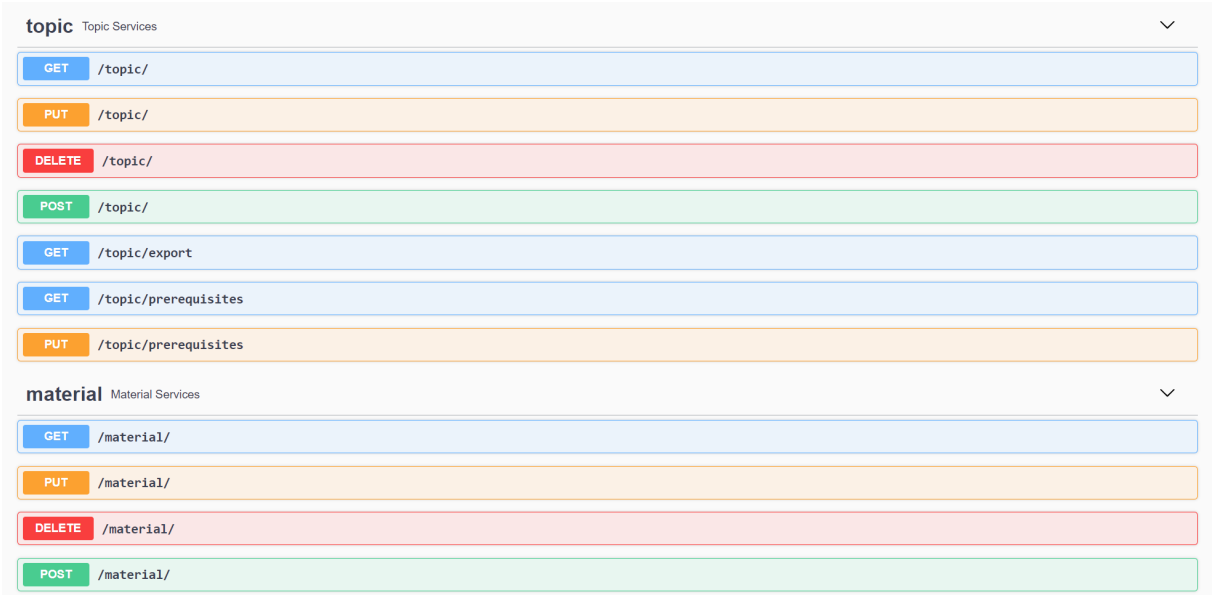

Figure 4.8: API endpoints for the system

4.4 Database Design

The following shows what the database schema for the system looks like. Many of the fields in the tables have been included in preparation for extending the system to include more features such as adding different versions of Learning Materials for a Topic and an authentication system.

Learning Materials in the database was original stored using file paths and the files would be

saved to the disk. However, it had later been modified to store files directly in the database as base64 encoded data URLs to ensure data integrity as well as personal experiences in working with base64 encodings.

```
DROP TABLE IF EXISTS "USERS";
CREATE TABLE IF NOT EXISTS "USERS" (
    "id"            INTEGER,
    "email"         TEXT NOT NULL,
    "name"          TEXT NOT NULL,
    "password"      TEXT NOT NULL,
    "curr_token"    TEXT NOT NULL,
PRIMARY KEY("id")
);

DROP TABLE IF EXISTS "MATERIALS";
CREATE TABLE IF NOT EXISTS "MATERIALS" (
    "id"                        INTEGER,
    "name"                      TEXT NOT NULL,
    "file"                      TEXT NOT NULL,
    "time"                      INT NOT NULL,
    "creator"                   INT NOT NULL,
    "stage"                     INT NOT NULL,
    "version"                   INT NOT NULL,
    "topic"                     INT NOT NULL,
    FOREIGN KEY("creator")      REFERENCES "USERS"("id"),
    FOREIGN KEY("topic")        REFERENCES "TOPICS"("id"),
    PRIMARY KEY("id")
);

DROP TABLE IF EXISTS "PREREQUISITES";
CREATE TABLE IF NOT EXISTS "PREREQUISITES" (
    "topic"                         INTEGER NOT NULL,
```

```
    "prerequisite"                  INTEGER NOT NULL,
    FOREIGN KEY("topic")            REFERENCES "TOPICS"("id"),
    FOREIGN KEY("prerequisite")     REFERENCES "TOPICS"("id"),
    PRIMARY KEY("topic", "prerequisite")
);

DROP TABLE IF EXISTS "TOPICS";
CREATE TABLE IF NOT EXISTS "TOPICS" (
    "id"                            INTEGER,
    "title"                         TEXT NOT NULL,
    "description"                   TEXT NOT NULL,
    "group_name"                    TEXT NOT NULL,
    "discipline"                    TEXT NOT NULL,
    "creator"                       INTEGER NOT NULL,
    FOREIGN KEY("creator")          REFERENCES "USERS"("id"),
    PRIMARY KEY("id")
);
```

4.5 Export Package Structure

There are 2 ways in which a Topic can be exported within the Meta LMS. The following sections will explain where the internal structure of the two exported packages look like.

4.5.1 export.zip

The export.zip file has a custom structure which is specifically defined based on the structure of the Learning Materials inside the Meta LMS. As it can be seen in the following diagram, within the ZIP file, there is a directory named by the Topic title. Within the Topic directory, the 4 stages of a Topic is represented as their own directories and contain the respective Learning Materials.

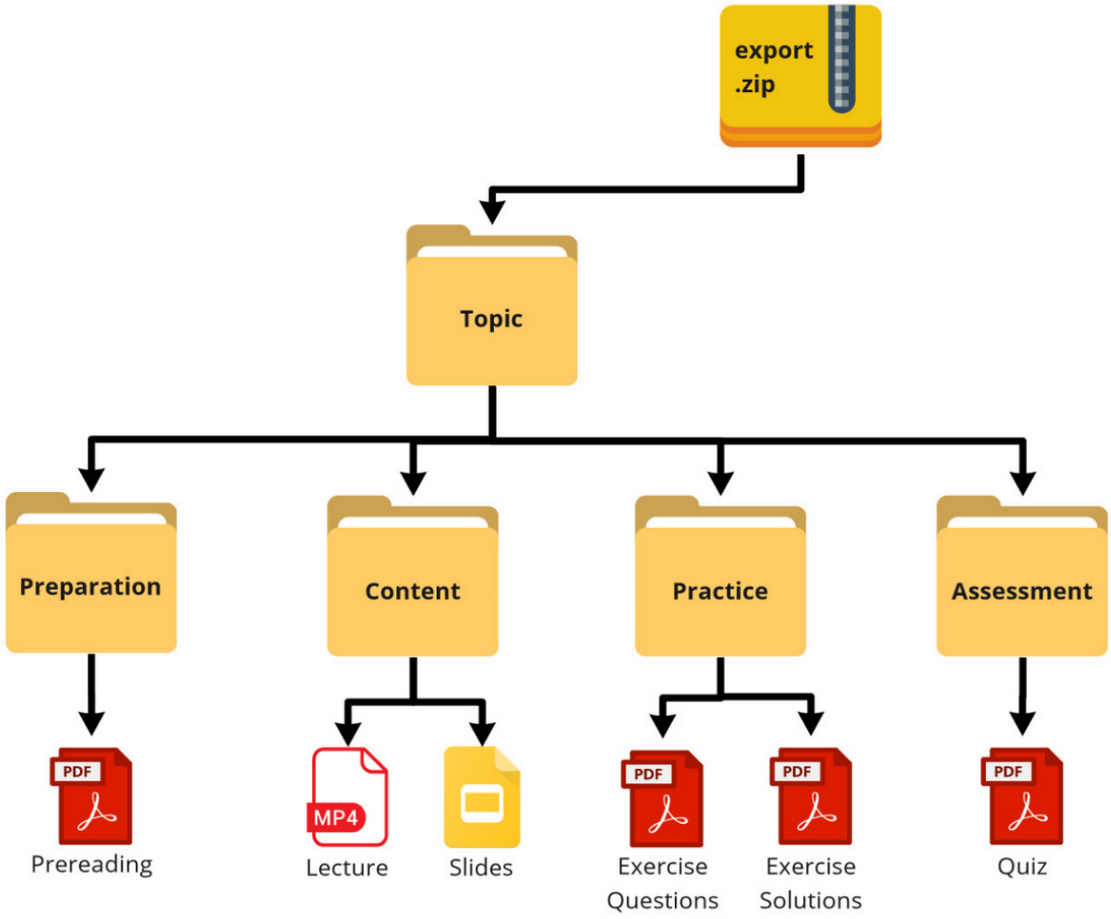

Figure 4.9: export.zip file structure

Additionally, a README.md file is included in each Topic directory to store the details relating to the Topic including the title, description, prerequisites, Group and Discipline the Topic belongs to.

Here is an example of the README.md.

```
Topic Overview
==============

# Topic
Strings
```

```
# Description
All about Strings
# Prerequisites of the Topic
None
# Group
C Programming
# Discipline
Computer Science and Engineering
```

In the original design of the structure, the export.zip did not have the extra layer where the stages of Learning Materials are stored within a directory for the Topic. However, after considerations allowing the system to be more open to extensions in the future, specially allowing the export of multiple Topics at once, the structure had been adjust so that it could cater for scenarios where export.zip contained multiple Topics as well as for one Topic.

4.5.2 export.imscc

A file with the .imscc extension can be known as a Common Cartridge package. Common Cartridge is a set of open standard developed and aim at enabling interoperability between content and systems. It is a file standard which is accepted by some of the most popular Learning Management Systems used in higher education such as Canvas and Moodle and hence was adopted as one of the options in which Topics can be exported from the Meta Learning Management System.

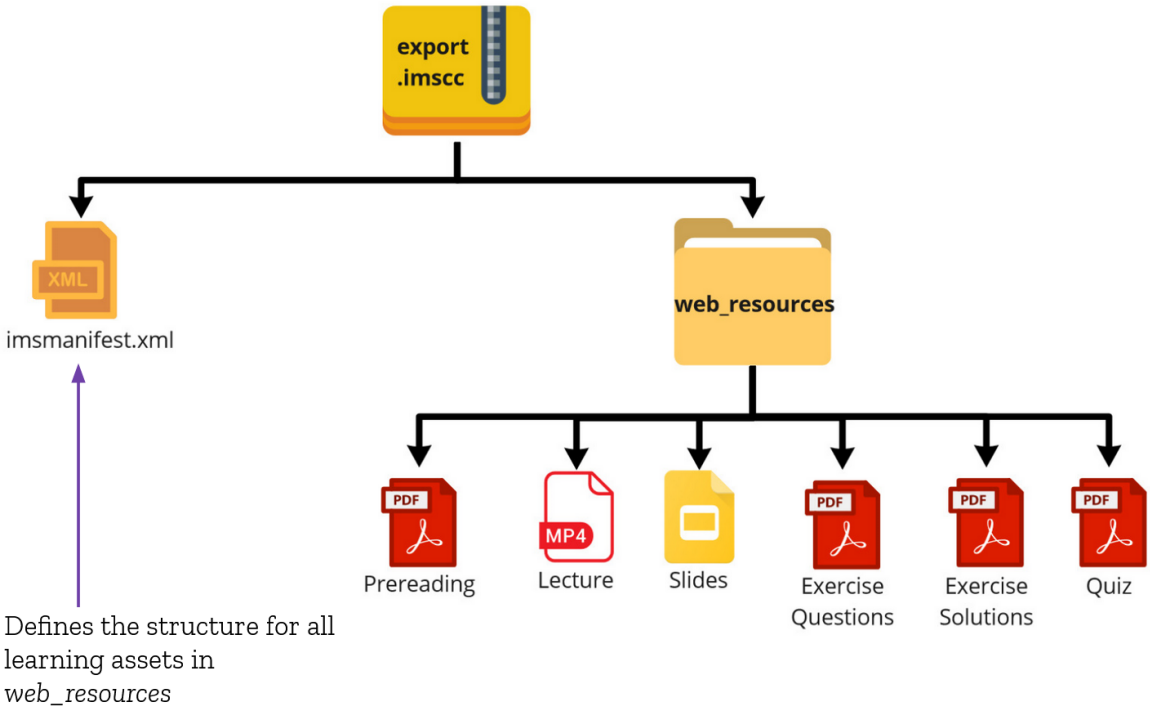

Figure 4.10: export.zip file structure

The above diagram explains the structure inside a Common Cartridge package. As shown in the Walkthrough in Chapter 5, importing a export.imscc exported from the Meta LMS into for example, Moodle, allows the structure of "Preparation", "Content", "Practice" and "Assessment" to be retained. This is achieved by the imsmanifest.xml file which describes the way in which the Learning Materials in the web_resources directory should be structured.

An small section of what the imsmanifest.xml file may look like is shown here:

```
33
34      <title>Strings</title>
35
36
37      <item identifier="strings-preparation">
38          <title>Preparation</title>
39      </item>
40
41      <item identifier="strings-preparation-str" identifierref="
        strings-preparation-str-ref">
42          <title>str.md</title>
43      </item>
44
45
46      <item identifier="strings-content">
47          <title>Content</title>
48      </item>
49
50      <item identifier="strings-content-detailedarticle" identifierref="
        strings-content-detailedarticle-ref">
51          <title>DetailedArticle.html</title>
52      </item>
53
```

Figure 4.11: Section of code from imsmanifest.xml

Most of the materials and categorisation are performed by the item tags in the xml file.

Chapter 5

Walkthrough

This section provides a walkthrough of the proof of concept Meta Learning Management System implemented as a part of this thesis. It describes how a User can navigate around the interface and further discusses some of the justifications behind why the interface is designed this way (in addition to Section 4.2.1).

The network graph structure of the implemented system follows what has been explained in the earlier sections of Chapter 3.

This Chapter will refer to any academics and course convenors who may use the system as Users.

Each section will go through one of the following type of feature, matching the functional requirements in Section 3.3:

- Viewing
- Navigating
- Creating/Editing
- Exporting

5.1 Viewing/Navigating

5.1.1 Viewing All Topics and Prerequisites

The following image shows what a User sees when they first access the system.

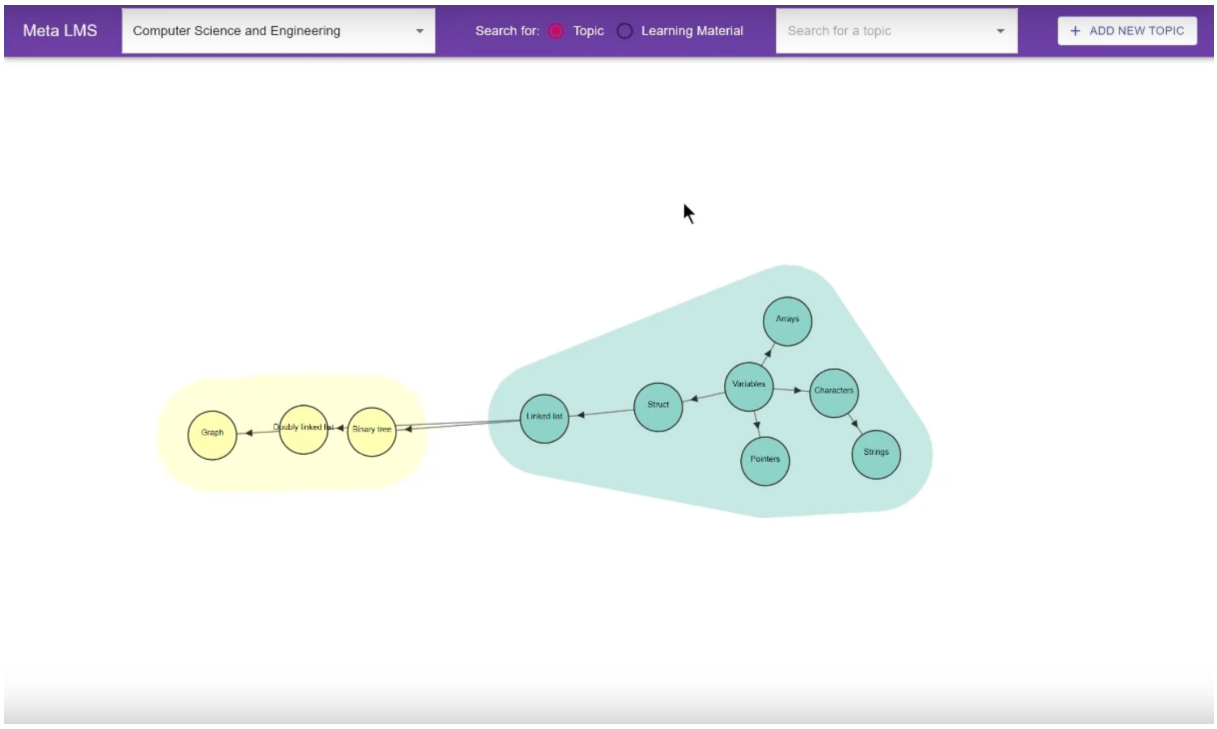

Figure 5.1: View when a User first accesses the system

As shown in the diagram, the User can view each Topic which already exists on the system as Topic Nodes in a network graph. The graph can be zoomed in and zoomed out using a scroll wheel. It can also be dragged around to allow Users to easily navigate to the section of the graph in which they would like to see. The coloured "bubble" which appears around a group of Topics highlights the Topic nodes which belong to the same Topic Group.

5.1.2 Viewing All Topic Groups

To allow convenient navigation around a large graph, the coloured "bubbles" identifying the Topic Groups within the graph are independently collapsible and expandable to view parts of

all of the graph at a higher level. The following image shows the collapsed Topic Group node of Data Structure and Algorithms.

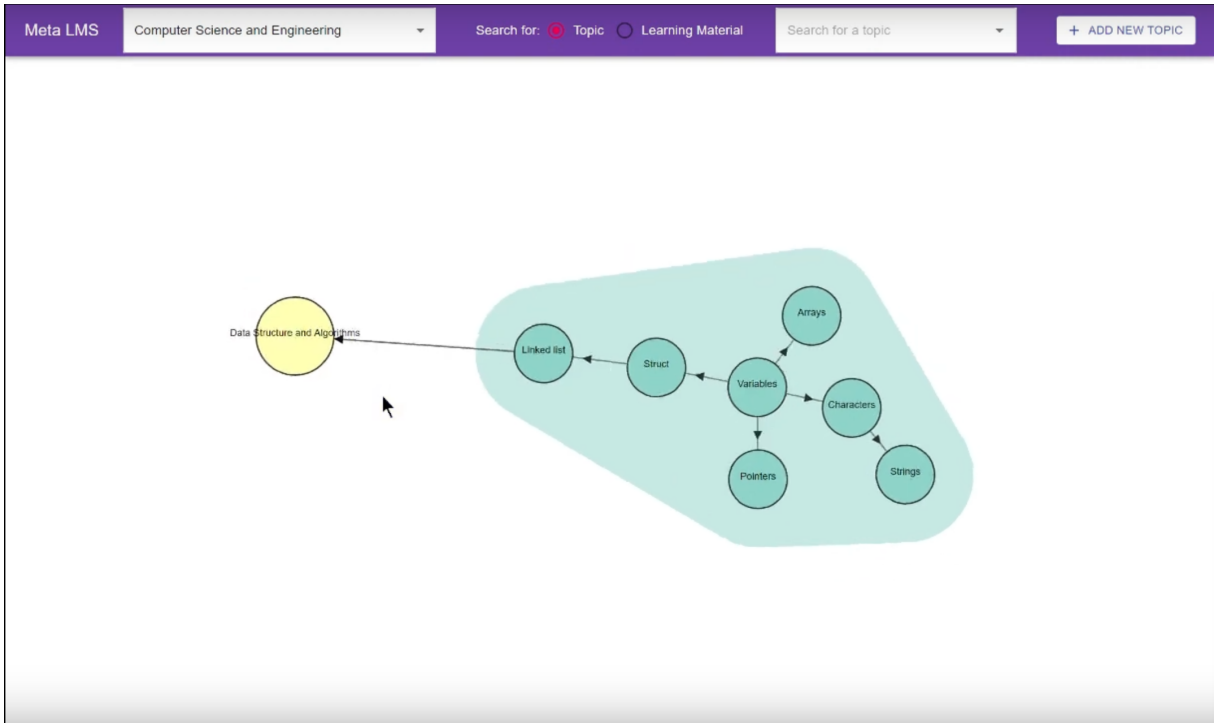

Figure 5.2: Groups of Topics can be collapsed into Topic Groups

5.1.3 Viewing a Specific Discipline

The User can choose to view the network graph of a different Discipline by changing the option on the dropdown on the left hand side of the navigation bar. The system will only show one Discipline at a time to reduce the amount of Topic nodes appearing on the graph which may not be of the User's interest.

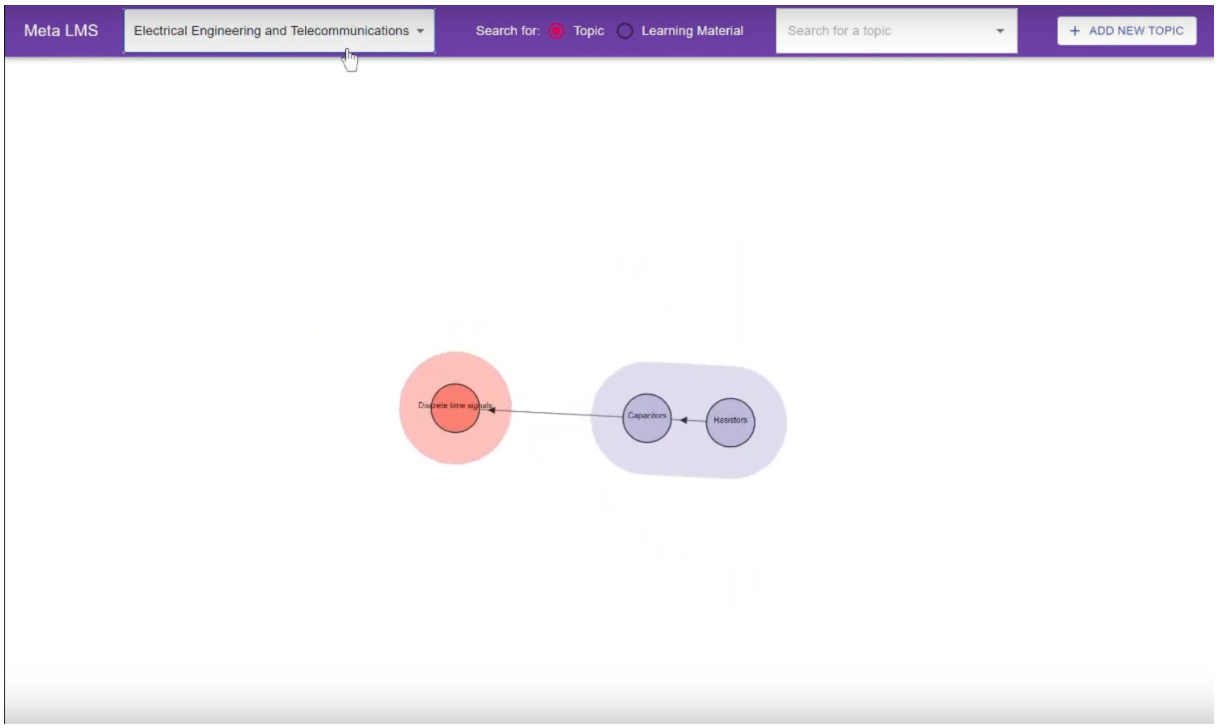

Figure 5.3: A User can navigate to a different Discipline's network graph

This current design as aforementioned in the UI Designs of Chapter 3 does not consider pre-requisite relationships which may occur across Discipline. Modelling the dependencies across Disciplines may be something to be considered in future iteration of the system.

5.1.4 Viewing Topic Details

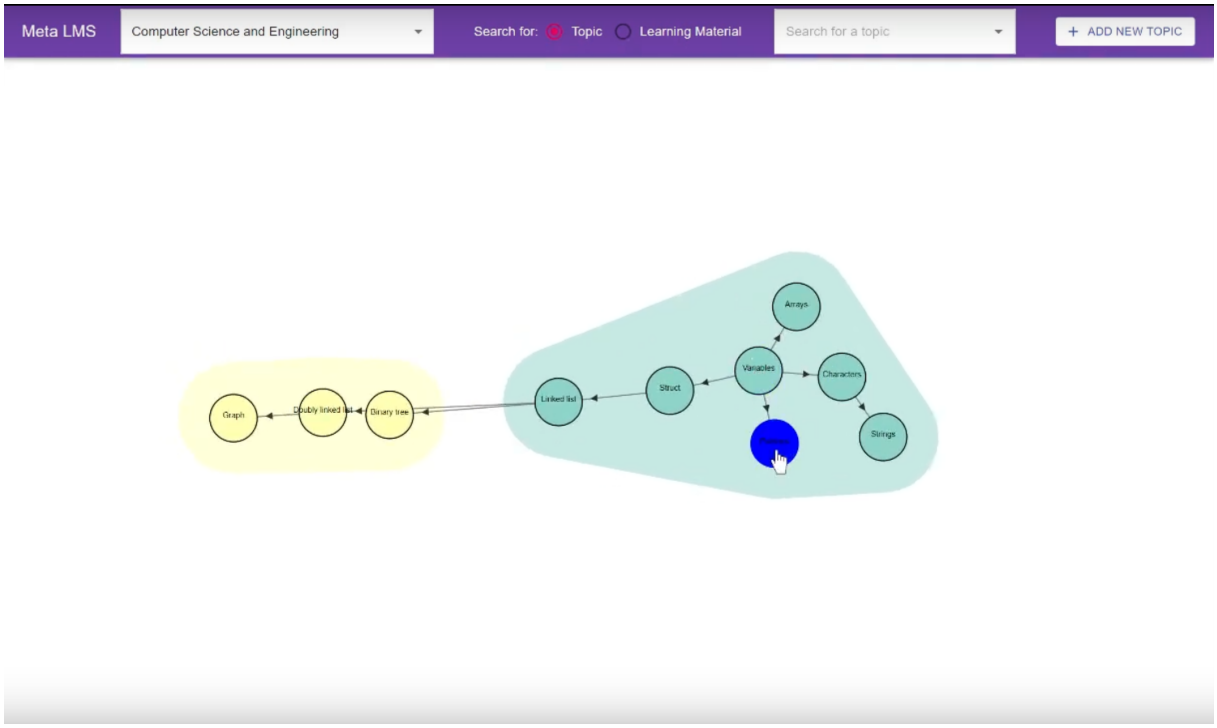

Figure 5.4: When the User clicks on a particular Topic node

If a User would like to view a particular Topic in more details, they can click onto the respective node as shown above and the details of the Topic will appear as an overlay. Topic details such as the title, description, prerequisites as well as the Topic Group and Discipline in which the Topic comes from will be shown in the center circle representing the graph node in this overlay.

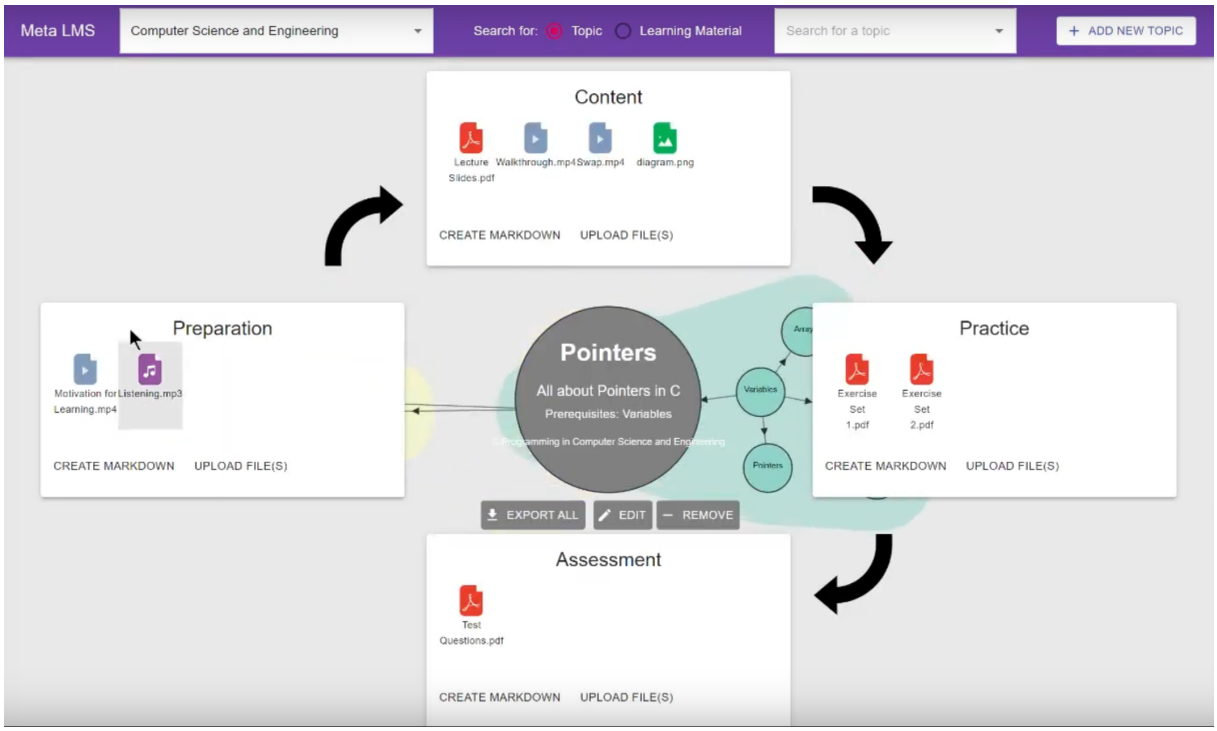

Figure 5.5: The Topic details of a Topic

Surrounding the centered node is the 4 stage learning process of Preparation, Content, Practice and Assessment which aims to model a student's learning process as aforementioned in Chapter 3. Learning Materials of various types relating to each stage for the particular Topic is shown within each of the white containers representing the stage.

If there are no Learning Materials for the stages, the a message will appear to let the User know this is the case.

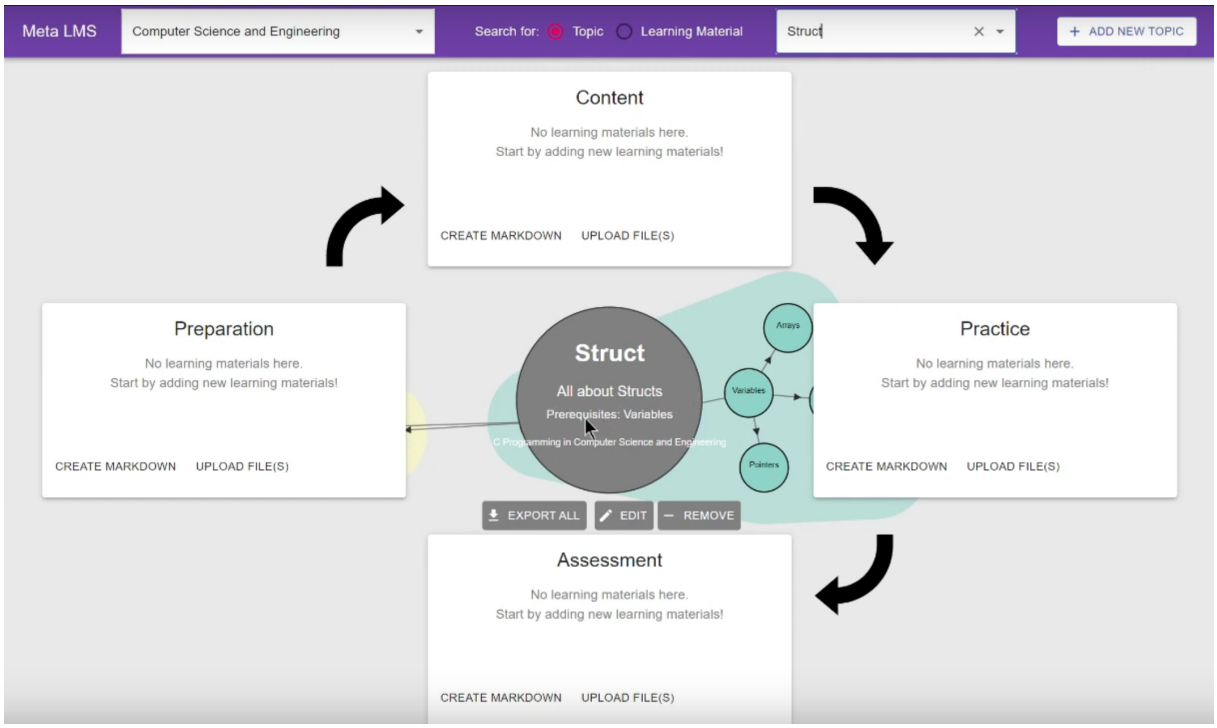

Figure 5.6: The Topic details of a Topic when there are no Learning Materials

When clicking onto a particular Learning Material within the Topic, the system will either display the content for the Learning Material as shown below.

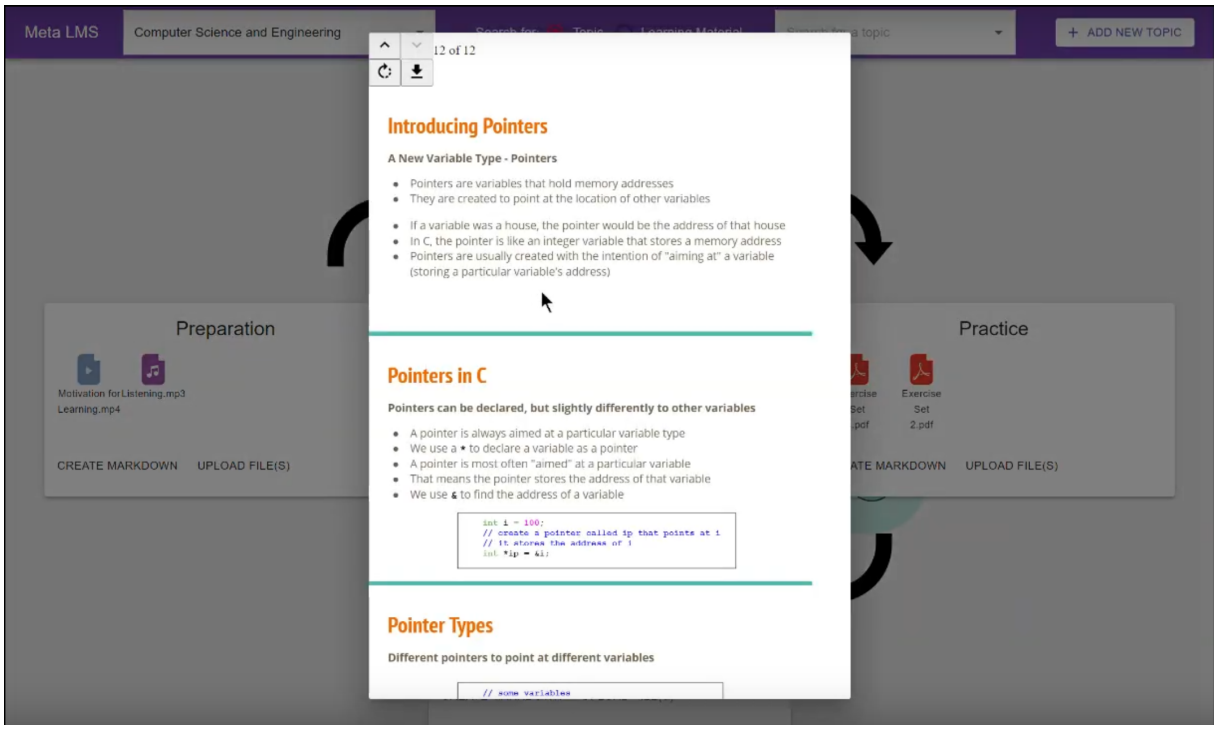

Figure 5.7: System displaying a preview of a PDF type Learning Material

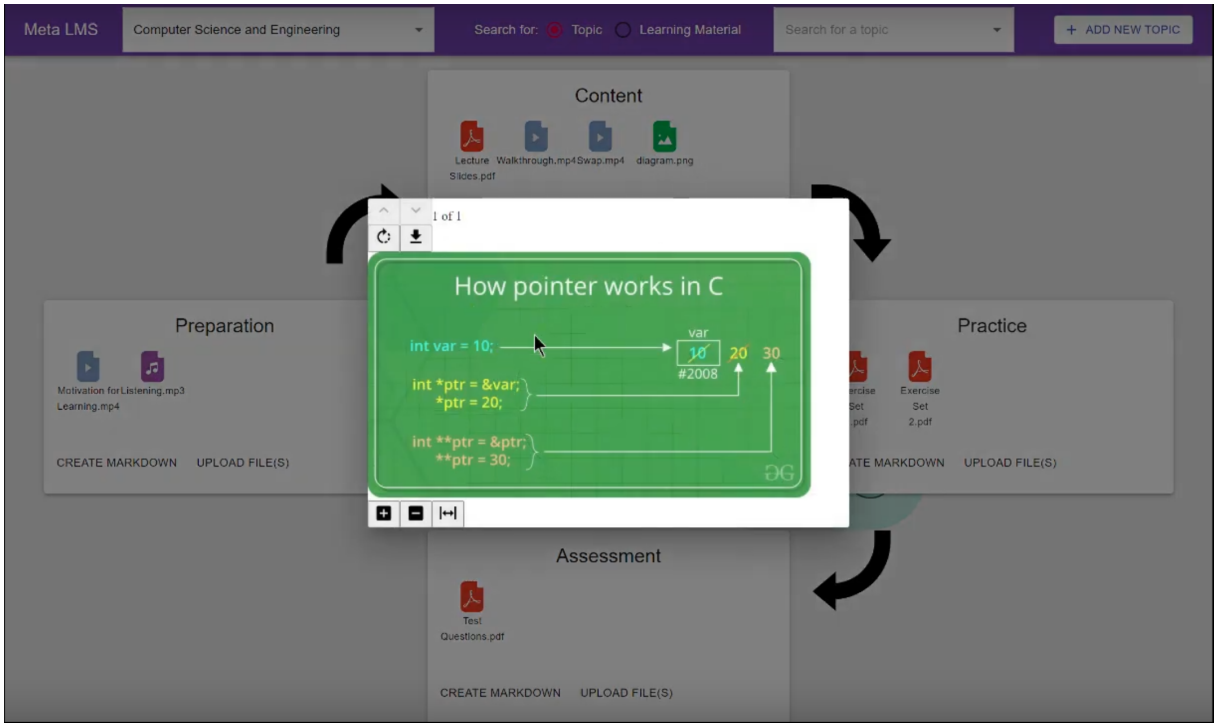

Figure 5.8: System displaying a preview of a PNG image type Learning Material

If this type of Learning Material is currently not supported on the system for preview (i.e. video and audio files), the system will show the following message.

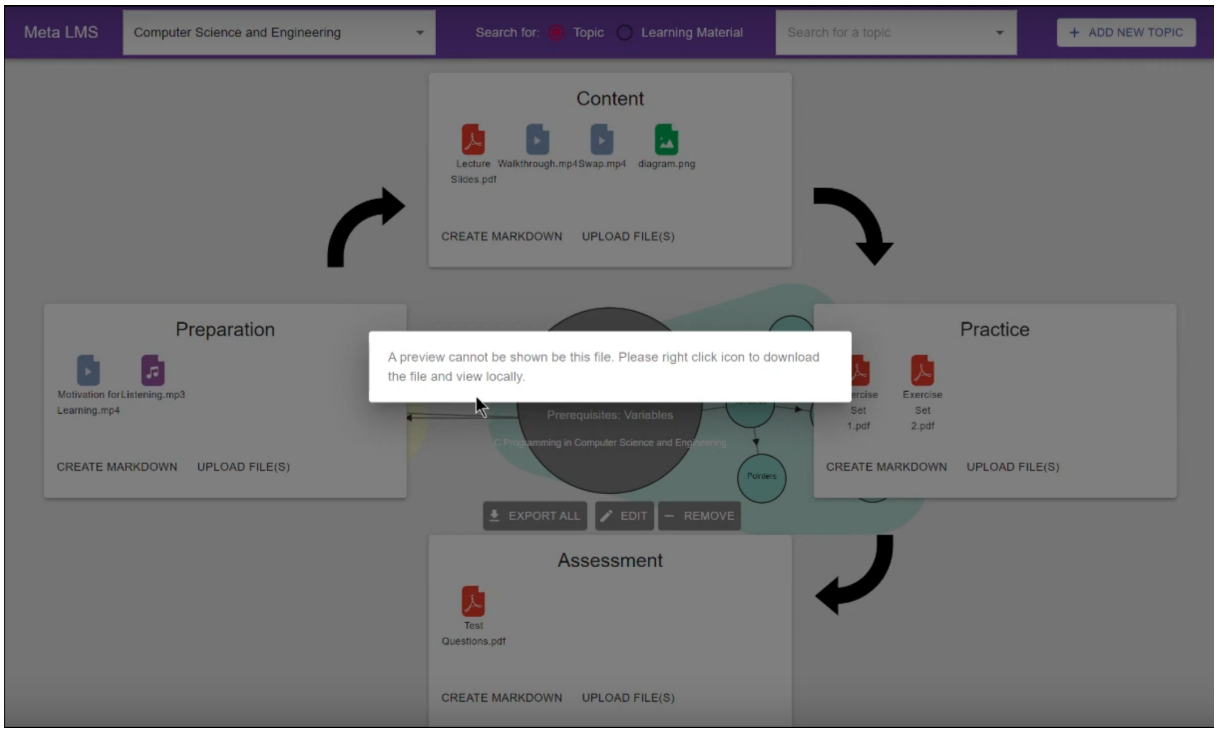

Figure 5.9: Preview message when a Learning Material cannot be displayed

5.1.5 Search through Topic Graph

To look for a particular Topic in the graph, the User can select "Search for Topic" on the top navigation bar then enter or select a particular Topic suggested by the search.

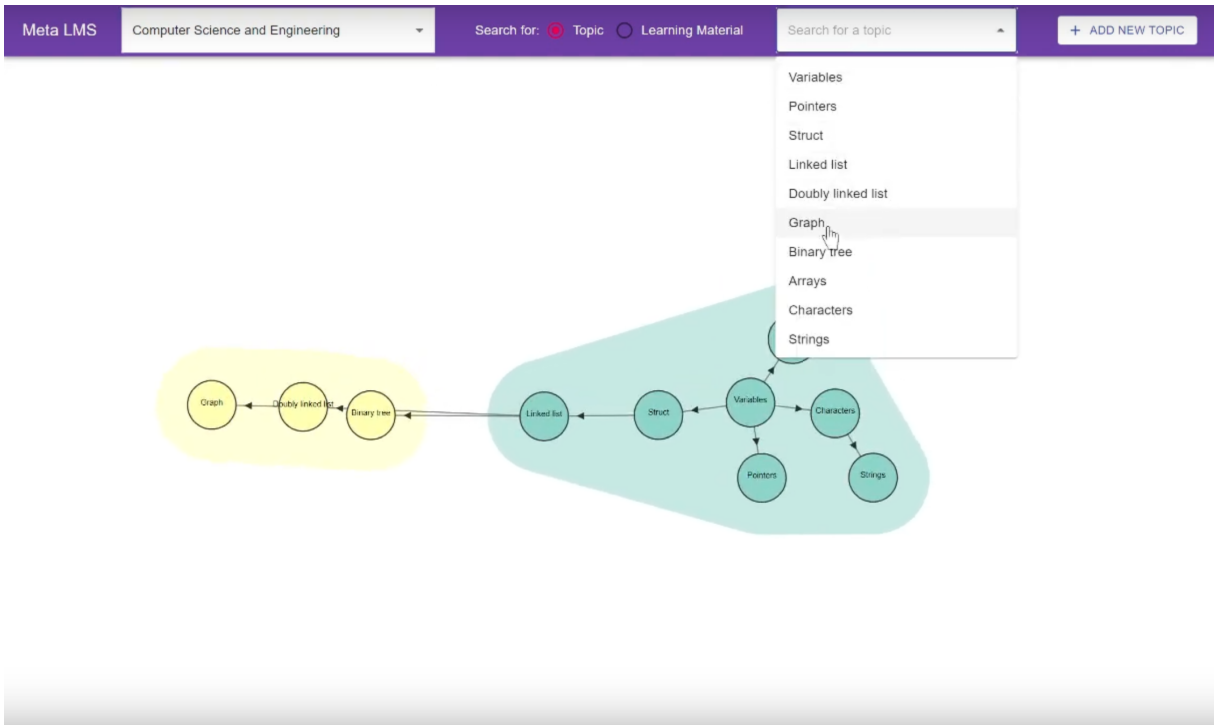

Figure 5.10: When a User searches for a Topic by title

When a Topic title has been entered to be searched by, the system shows the Topic details overlay for the selected Topic to the User like what is shown in Figure 5.5

If the User selects "Search for Learning Material" on the navigation bar, they can also search for particular Learning Materials or Topic by the name of the Learning Material as shown below.

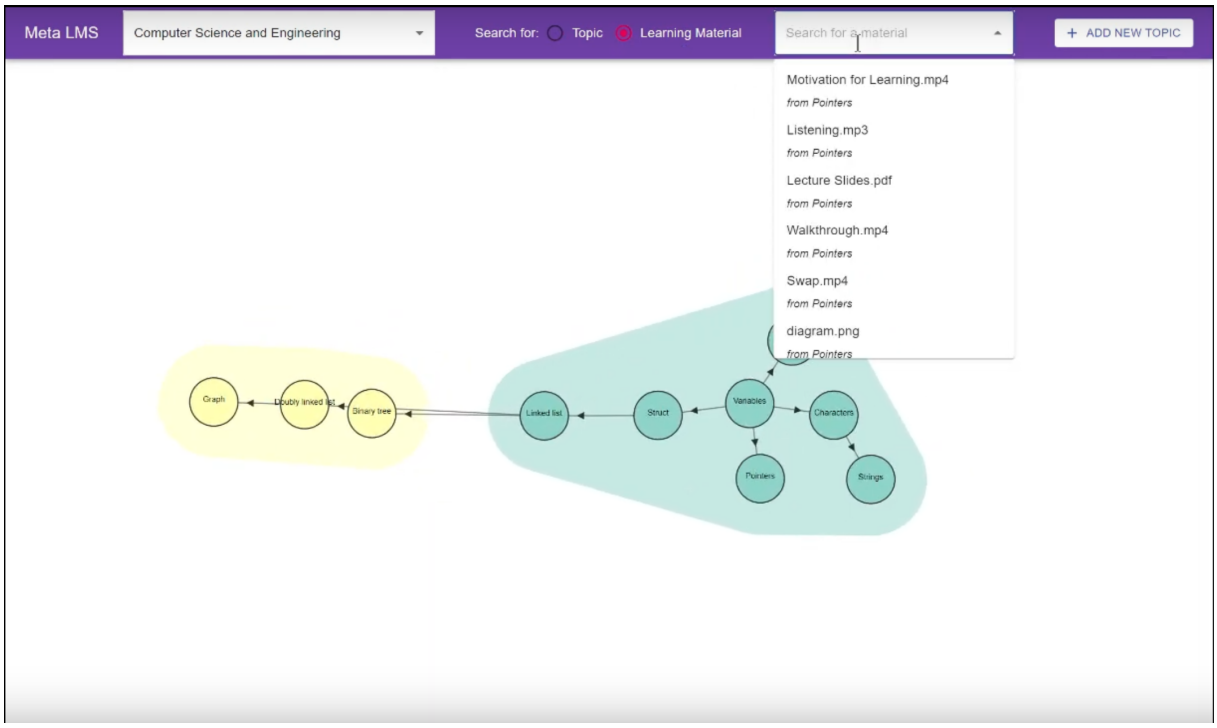

Figure 5.11: When a User searches for a Learning Material

Suggestions given in the search shows not only the Learning Material's name but also which Topic they belong to.

5.2 Creating/Editing

5.2.1 Topic

Create a New Topic

When a User would like to create a new Topic, they can do so by clicking the "Add New Topic" button which exists on the right hand side of the navigation bar. Once this button is clicked, the following interface is shown to the User for the User to enter in details.

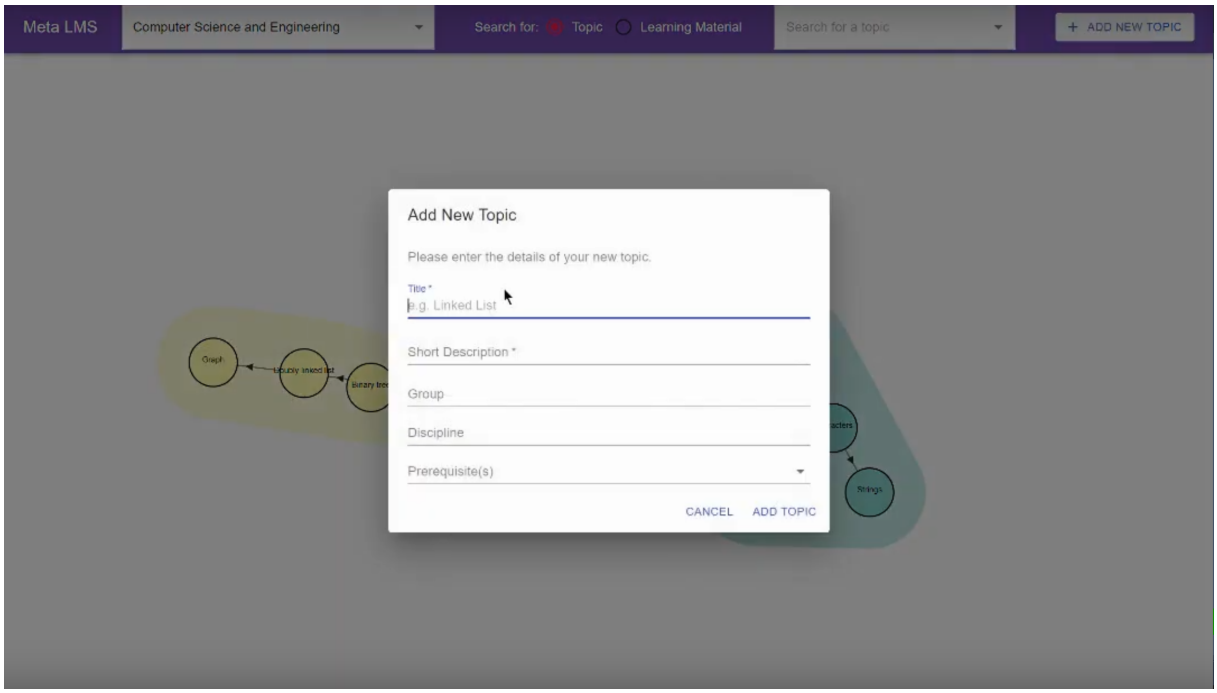

Figure 5.12: Interface shown to User for adding a new Topic

As seen in the Add New Topic interface, the User is prompted to enter some details about the new Topic they would like to add, namely, a title, short description, the Topic Group and Discipline in which the Topic would belong to as well as the prerequisites for the Topic.

The title and description fields both accept simple text input.

The Topic Group field is a dropdown which allows a User to choose an existing Topic Group. Alternatively, they can simply type in a different Topic Group title to add the new Topic into a new Topic Group. The Discipline field functions similarly to the Topic Group with a dropdown of suggestions. Exactly one Topic Group and one Discipline can be picked for a particular Topic to be added. An example of this is shown below.

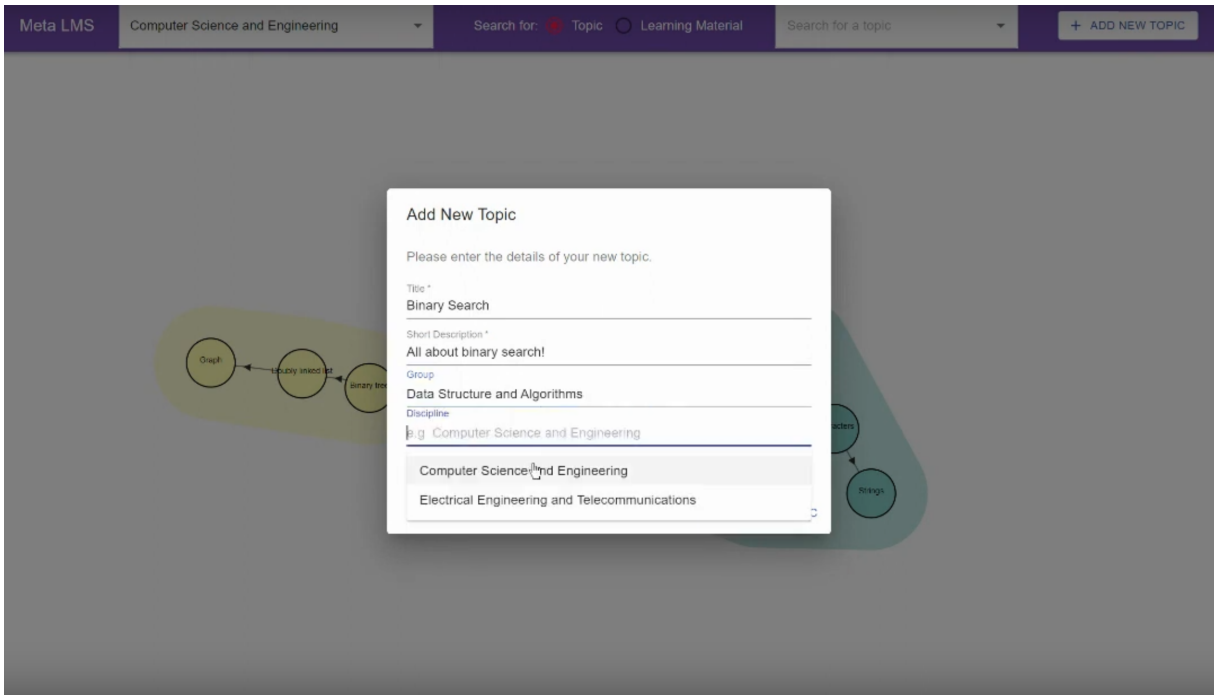

Figure 5.13: Dropdown for selecting a Discipline for a new Topic

Note that Topic Groups and Disciplines cannot and are not designed to be created independently; a new Topic Group or Discipline is created when a new Topic added belongs to a Topic Group or Discipline which does not currently exist in the system.

The input of prerequisites of a Topic uses a multi-select dropdown as it is possible for one Topic to have multiple prerequisites.

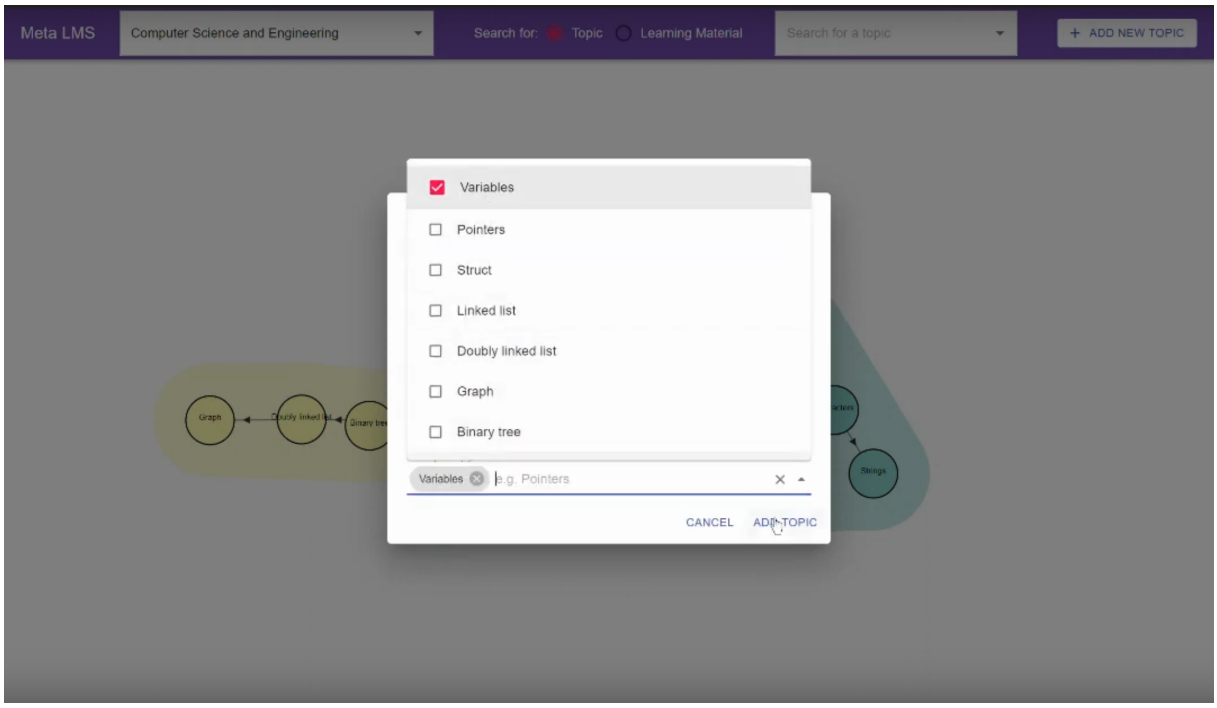

Figure 5.14: Multi-select dropdown for selecting prerequisites for a new Topic

If the Topic to be added is a duplicate of an existing Topic in terms of title, an error message letting the User know this is the case will be shown and the Topic addition will be rejected.

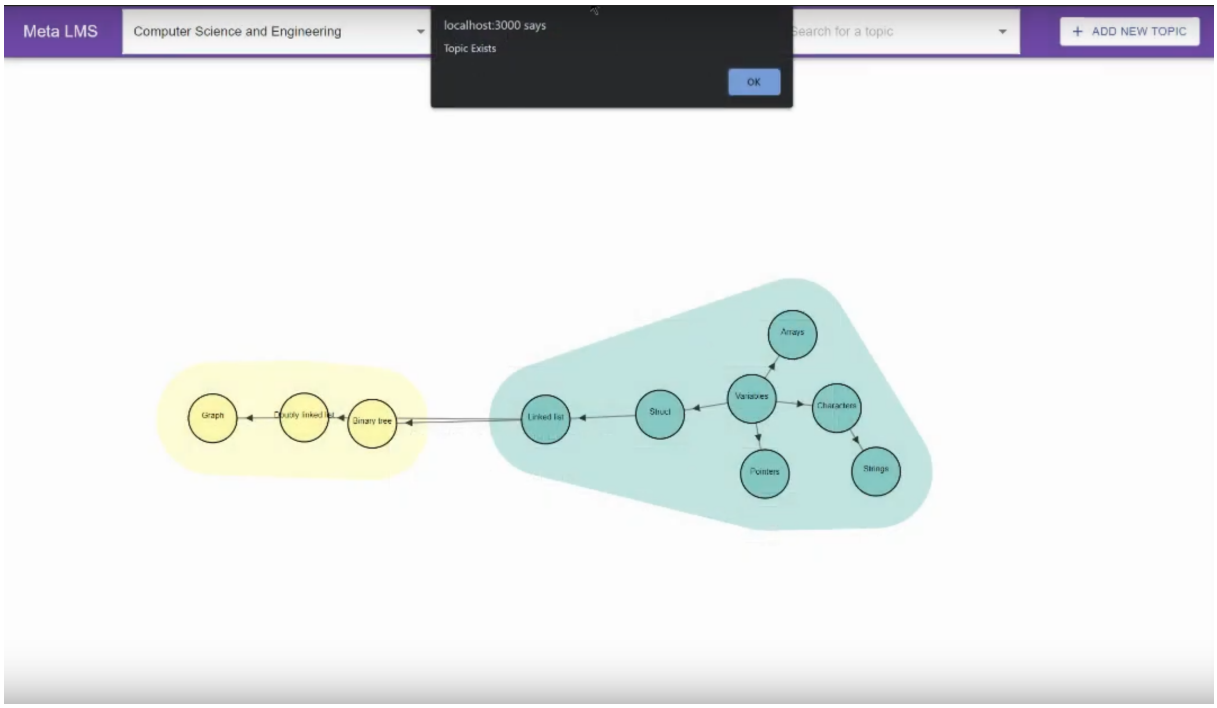

Figure 5.15: The system rejects the addition of a Topic if it already exists

Edit an Existing Topic

When a User would like to edit an existing Topic, the "Edit" button in the Topic details shown in Figure 5.5 will allow an interface similar to the popup shown when adding a new Topic (Figure 5.12).

The notable difference is that, the fields of the popup will be prepopulated with existing details about the Topic. The User can freely update each of the fields for the details of the Topic and the change will be reflected immediately by the system.

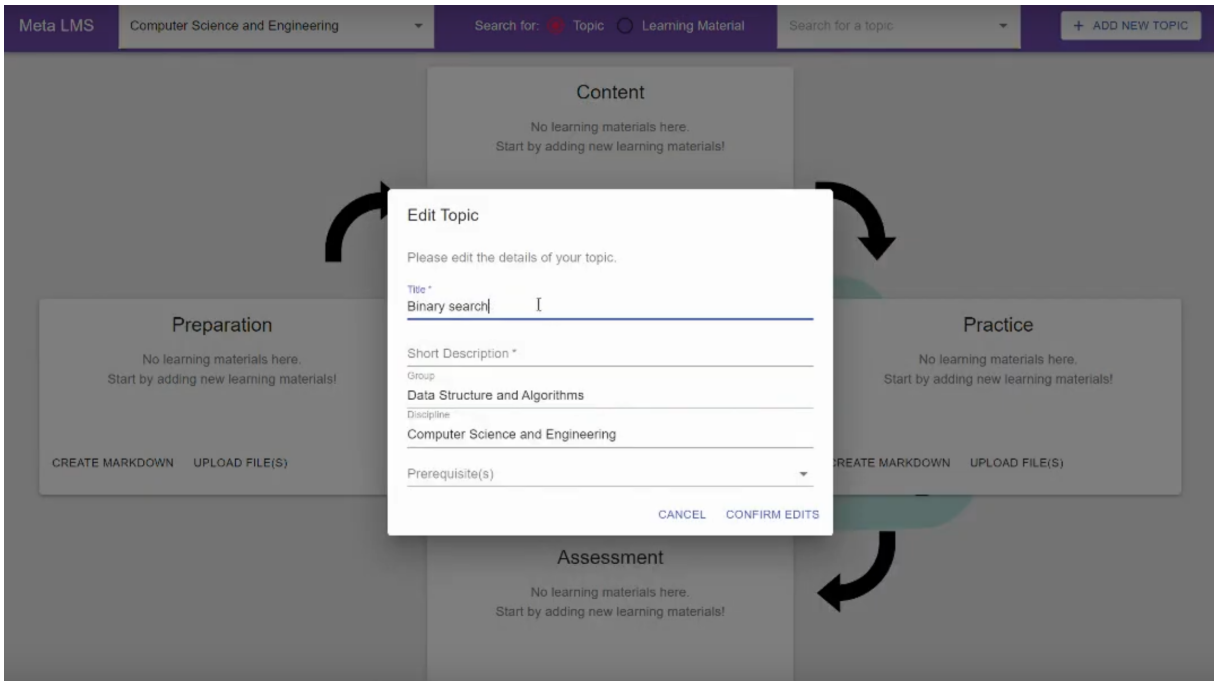

Figure 5.16: Interface for editing a Topic

There are two edge cases in which the system also caters for when a User edits a Topic; when the User changes the Topic title to be of a duplicate of an existing Topic or when the User attempts to update the prerequisites in a way which causes a cycle to be formed.

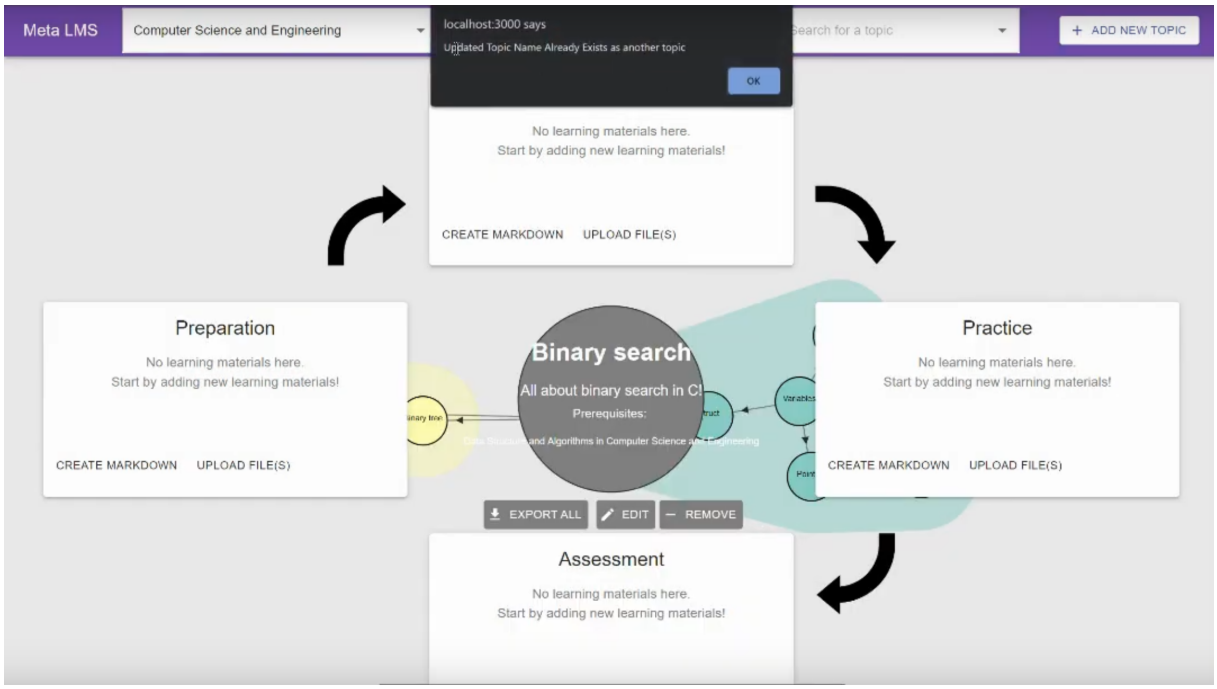

Figure 5.17: Error message shown when edits made to a Topic would cause duplication

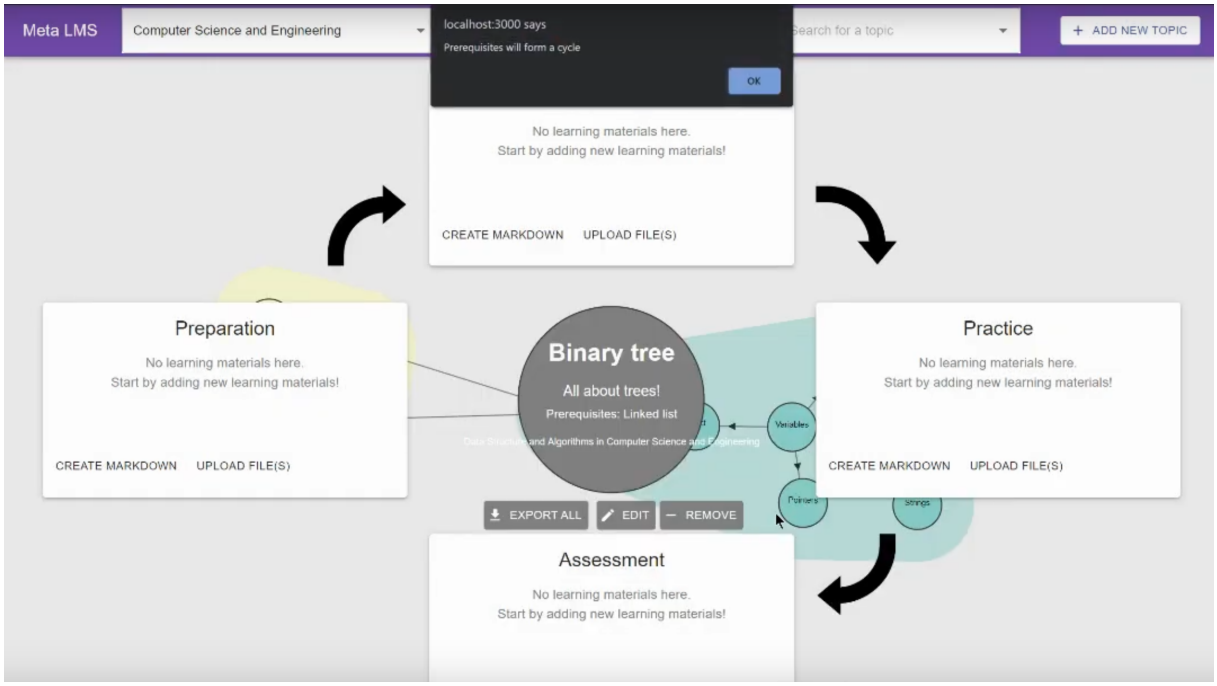

Figure 5.18: Error message shown when edits made to a Topic would cause a cycle to be formed in the graph

Remove an Existing Topic

If a User would like to remove a Topic which exists on the graph in the system, they can do so by clicking the "Remove" button in Figure 5.5

Removing a Topic will cause the Topic node and all of its Learning Materials to be removed. Topics which depend on the Topic removed as prerequisite will be left with no prerequisites unless the User makes any more updates.

In short, all incoming and outgoing connection of the Topic is removed and reflected on the graph.

5.2.2 Learning Material

Upload a New Learning Material

A User can populate a Topic in the system by uploading Learning Materials in the form of files. Using Figure 5.6 as an example, the User can click the "Upload Files" button corresponding to the stage in the Topic in which they would like to upload a Learning Material to. The following shows an example of what the User may see once they choose to upload Learning Materials to a stage.

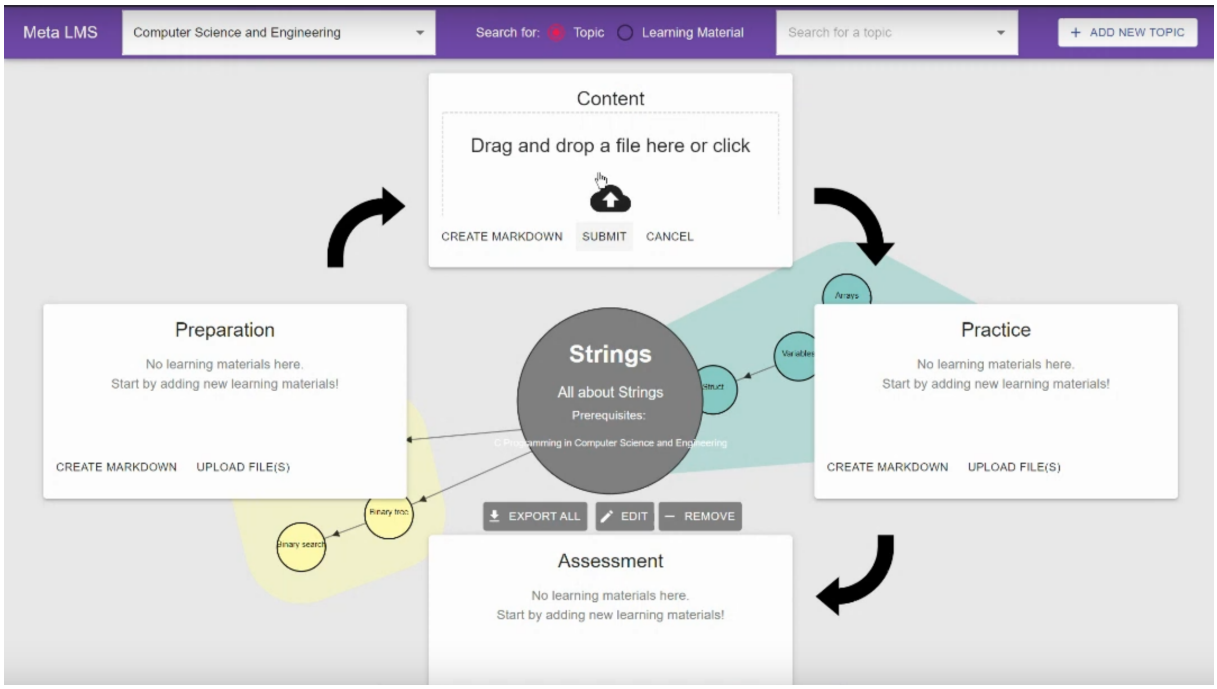

Figure 5.19: The interface when a User chooses to upload Learning Materials to the Content stage of a Topic

The User can click or simply drag and drop file(s) from their local disk into the area shown and click "Submit" to save the files on the system.

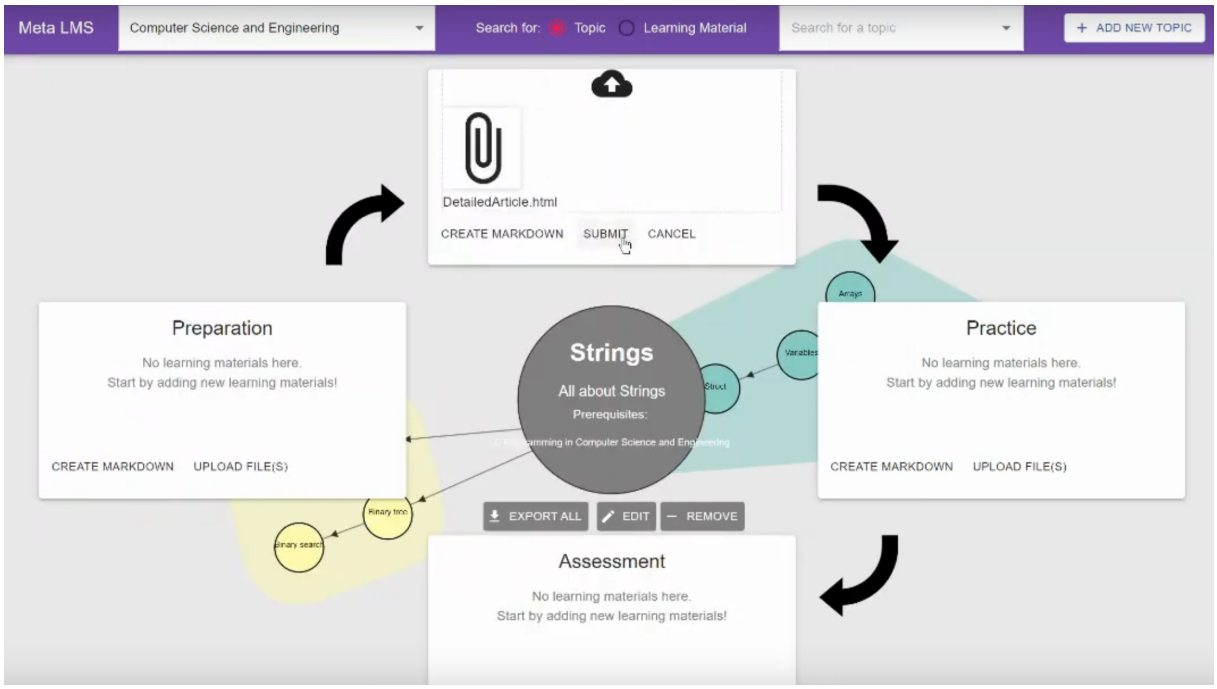

Figure 5.20: The interface when User is uploading Learning Materials to a Topic

Create a New Learning Material

Learning Materials can also be created on the system in the form of a Markdown file. This may be particularly useful if a User needs to create a Learning Material under a short amount of time. To create a Markdown on the system, on the interface shown in Figure 5.5, the User can simply select the "Create Markdown" button on the stage of the Topic in which they would like the file to reside in. A Markdown editor will then be shown to the User.

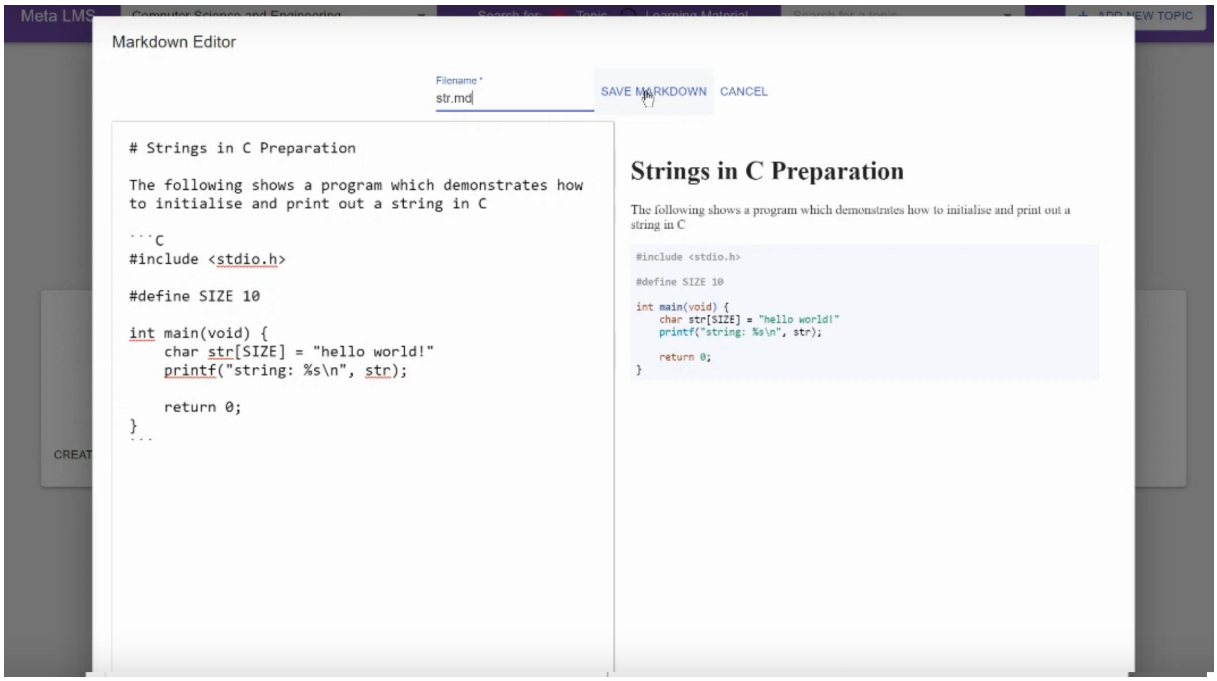

Figure 5.21: The Markdown Editor with some content

The Markdown editor supports plain text input, code syntax highlighting as well as the inclusion of links or images. Once the User finishes adding content into the editor, they can provide a filename and click "Save Markdown" to save it as a Learning Material on the system in the select stage of the Topic.

Edit an Existing Learning Material

The system allows a User to edit any Markdown files that exists in a Topic. This is performed by clicking on a Markdown type Learning Material within a Topic which will prompt the system to bring up the Markdown editor for the User to make edits. (Figure 5.21)

Remove an Existing Learning Material

If the User would like to remove an existing Learning material on the system, they can simply right click on the item to bring up the context menu and select "Remove" as seen in the following

image.

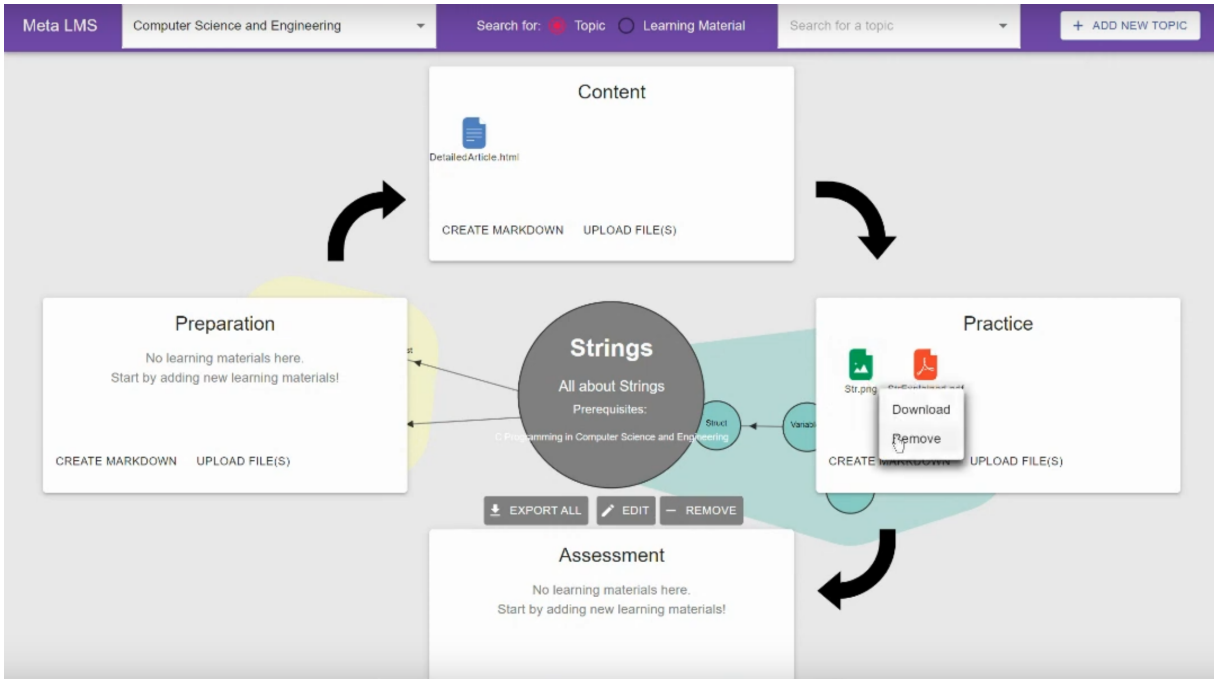

Figure 5.22: The context menu when right clicking a Learning Material on the system

5.3 Exporting

5.3.1 Download a Learning Material

A specific Learning Material can be downloaded from the system by selecting "Download" in the context menu in Figure 5.22 which will prompt the file to be downloaded and saved to the User's local disk.

5.3.2 Export an Entire Topic

There are 2 ways of exporting a Topic on the system:

1. Export as a ZIP file (.zip)

2. Export as a Common Cartridge package (.imscc)

The selection of how to export a Topic can be made when the User clicks on "Export All" within the Topic details interface as shown below.

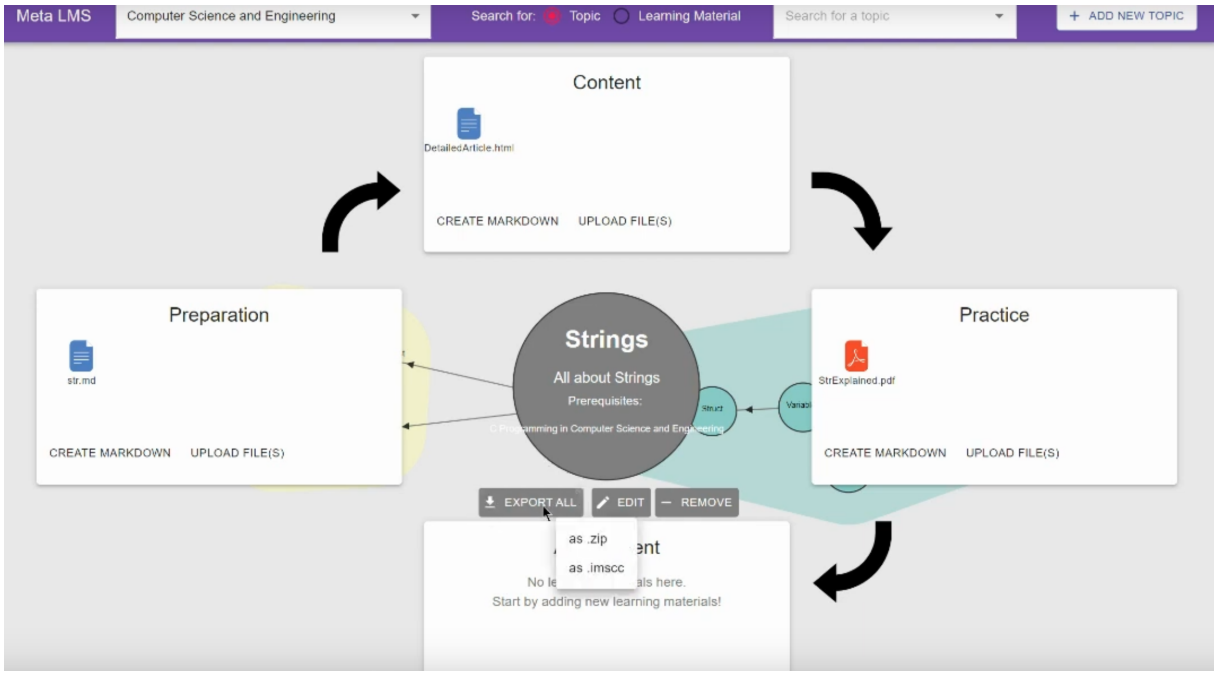

Figure 5.23: The context menu when right clicking a Learning Material on the system

When the User chooses to export a Topic as a ZIP file, an export.zip will be saved onto the User's local disk.

When the User chooses to export a Topic as a Common Cartridge package, an export.imscc will be saved onto the User's local disk. A file with the .imscc extension can be imported into any Learning Management Systems which supports it. Once imported, the Learning Materials within the Topic will retain its structure of Preparation, Content, Practice and Assessment from the Meta LMS on the LMS. An example is shown in the following two images.

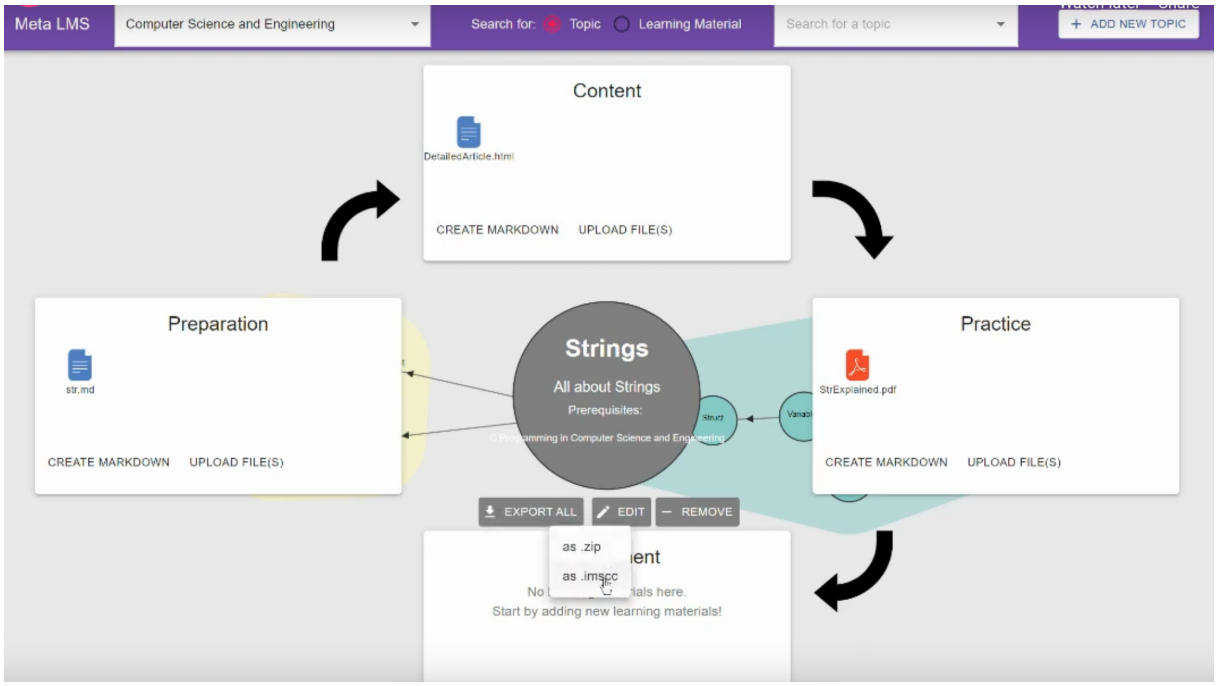

Figure 5.24: When the User chooses to export a Topic as a .imscc file

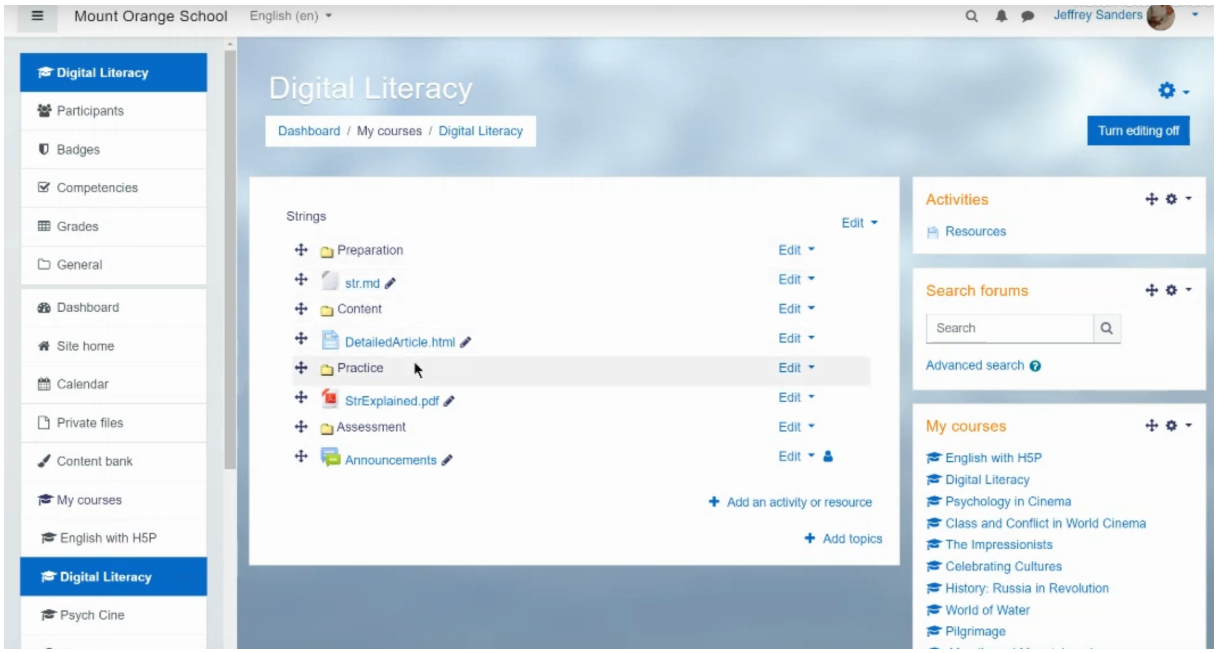

Figure 5.25: When the User imports a .imscc file exported from the Topic above

The internal file structure of both export.zip and export.imscc are described in Section 4.5 of

this report.

Chapter 6

Analysis

This section proposes an analysis framework and examines the implemented system based on this framework to determine how the system is from achieving its intended purpose and how well it functions.

There are 4 ways in analysing the system:

1. **Functional Requirements Fulfilment** - Does the system satisfy the functional requirements planned?
2. **Non-Functional Requirements Fulfilment** - Does the system satisfy the non-functional requirements planned?
3. **Reusability and Efficiency Analysis** - Does the system encourage more *reusable* content and *efficient* processes?
4. **Feedback from Potential Users of the system** - What do potential Users think about the system?

6.1 Functional Requirements Fulfilment

The functional requirements fulfilment analysis is conducted by going through the implemented system and comparing the final behaviours of the system against the requirements and acceptance criteria described in Section 3.3 of this report.

Under each requirement in Section 3.3, the acceptance criteria satisfied have been marked with a tick on the criterion's left hand side and a marked if it was not satisfied. Additionally, based on the degree of completion of the acceptance criteria, the Status of completion of each requirement has also been noted in each requirement. The definitions of how each Status is defined is noted in Section 3.3.

The following table summarises the completion Status of the requirements;

Requirement Status	**Number of Requirements**
Complete	13
Mostly Complete	2
Not Complete	3
	Total: 18

From the above table, it can be seen that majority of the requirements planned for the system had been completely implemented.

The following outlines the 2 requirements which have been marked as "Mostly Complete" as well as the reason for this Status;

- **Search through the Topic Graph by keywords** - At present, the system allows Users to search through the given Topic Graph by Topic title or the file name of Learning Materials. However, although specified in the acceptance criteria, the system is currently not capable of searching the Topic Graph via Topic Group titles. This is mostly due to limitations on the amount of time which remained for the implementation of this feature. This feature had been added in later in the implementation process.
- **Create a new Topic** - A User can create a new Topic in system, however one of the acceptance criteria requires the system to automatically suggest Topics if the Topic to be

added is similar in title to existing Topics. This had been informally deprioritised during the implementation process since it is possible for the User to search by Topic title to determine whether an existing Topic is similar to what they would like to add and then proceed to make the addition if necessary. More time would be required to add a feature in this system to completely meet this criterion.

The following outlines the 3 requirements which have been marked as "Not Complete" as well as the reason for this Status;

- **Edit existing Learning Materials** - It is possible for the User to edit Markdown type Learning Materials on the system but since the acceptance criteria of this requirement also expects the system to allow the reupload of Learning Materials, based on the definition of the Statuses, this requirement is naturally marked as "Not Complete". Despite this, it is still possible for a User to achieve the same outcome as a reupload feature by simply performing a removal on the Learning Material and adding an updated version of it into the system again.
- **Create multiple versions of Learning Materials for a Topic** - This requirement has a priority of [Won't Have]. There had been no intention for this requirement to be implemented within the time provided for this thesis. It is however a potentially useful feature for the system hence it has been explicitly mentioned in the list of requirements but marked as "Not Complete".
- **Export a Topic Group** - It is currently only possible to export a Topic, but not a Topic Group from the system (stated in Section 3.3). As aforementioned, the notion of Topic Group was introduced later in the implementation process. As a consequence of this, more time would be required to add this feature in the system.

6.2 Non-Functional Requirements Fulfilment

The non-functional requirements fulfilment analysis can be conducted by examining each of the non-functional requirements planned for the system and discussing to what degree each of the

requirements have been achieved.

The following sections will analyse and discuss the non-functional requirements in relation to the implemented system.

6.2.1 Extensibility

Extensibility is concerned with whether the system is open to the addition of new features and functionalities. In the case of the Meta LMS, a few steps have been taken to attempt to make this system extensible. This includes setting up the database in a way which assumes the existence of potential future features so that if the features were implemented in the future, the database may not necessary need to be redesigned. Additionally the export files structures (.zip and .imscc) from the system both have been designed to take in consideration of future extensions. For example, as mentioned in Chapter 4, the file structure of the ZIP file has been designed to ensure if a feature to export a Topic Group were to be implemented in the future, the ZIP structure can cater for it without needing to be redesigned.

6.2.2 Performance

In terms of the performance of the system, on the backend, as an attempt to achieve modularity, performance in terms of response time has been sacrificed. For example, if a particular action is performed by a User on the frontend, the system may make multiple request to the backend in order to satisfy the need of the User. This is a non-functional requirement which needs to be improved on in future iterations of the system, achieving both modularity and good performance.

6.2.3 Security

Unfortunately, as the system is a proof of concept, although security and authentication is extremely important in the system, it had been deprioritised to allow more features which demonstrate the general idea of this thesis to be implemented.

6.2.4 Data Integrity

As an attempt to achieve data integrity where data is consistent throughout the system. There is a single source of truth in the system, that is the database. Learning Materials in the system have been stored as base64 encodings in the database rather than on the disk which could be prone to being modified and eventually become out of sync with the information in the database depending on how it is implemented.

6.3 Resuability and Efficiency Analysis

This section of the analysis is focused on examining the system against the overall aim of the thesis; Does the system encourage more *reusable* content AND *efficient* processes?

As an attempt to objectively answer this question, we will simulate workflows of academics and course convenors, noting down the steps taken. Comparisons will be made between the usual workflows which academics and course convenors may go through when creating courses with the potential workflows which they may undergo if they use the Meta Learning Management System to assist them in the process. For the purpose of this analysis, it will be assumed that content for a course are created in one sitting.

For the remainder of this section, academics and course convenors will be referred to as Users.

As Moodle is one of the more popular existing Learning Management Systems within higher education around the world including at UNSW, it has been selected as the Learning Management System we will use to simulate the workflows.

The following describes the scenarios that will be simulated and used for comparison as well as the course to be created in the scenario:

- **Scenario 1:** Rolling over to a new course offering of a particular course with and without the assistance of the Meta Learning Management System. UNSW's COMP1511 Programming Fundamentals course will be used as the example here.

- **Scenario 2:** Creating a brand new course which largely overlaps with existing Topics with and without the assistance of the Meta Learning Management System. UNSW's COMP1911 Computing 1A course will be used as the course to be created.
- **Scenario 3:** Creating a brand new course where only a small subset of Topics which overlap with and without the assistance of the Meta Learning Management System. UNSW's COMP2521 Data Structures and Algorithms will be used as the course to be created.
- **Scenario 4:** Creating a brand new course where there are no overlaps with existing Topics with and without the assistance of the Meta Learning Management System. UNSW's COMP2041 Software Construction course will be used as the course to be created.

The above courses has been selected due to personal experiences and understanding with the courses from a student's and an academic tutor's perspective to allow the comparison to be conducted from as close to an academic or course convenor's point of view as possible.

To allow the results to be measurable so that they can be easily comparable, the notions of *reusability* and *efficiency* have been quantified;

- **Reusability** is measured by a percentage calculated using the following formula:

$$\frac{R}{T} * 100 \tag{6.1}$$

  where,
  R = Number of Topics where Learning Materials come from reusing existing and available resources and,
  T = Total number of Topics designed in this course to be created.
- **Efficiency** is measured by the number of steps required to perform the given scenario. The lower the number, the more efficient the system is for the particular scenario.

Please note that it is important to distinguish between the term Efficiency discussed in this section of the analysis compare to the term Efficiency referred to in the non-functional requirements.

6.3.1 Preparation

Before simulating the scenarios as described previously, assumptions about the system and what resources already exist prior to the scenarios need to be clearly defined.

For all of the scenarios performed, the following assumptions will be made:

- The Topics and Learning Materials relating to the course COMP1511 Programming Fundamentals at UNSW already *exists* on Moodle. Whether these resources are *accessible* by the User depends on the scenario performed and will mimic the actual situation at UNSW (to be described in the scenarios following in more details).
- The Topics and Learning Materials relating to the course COMP1511 Programming Fundamentals at UNSW already *exists* as Topics within the Topic Group "C Programming" under the Discipline of "Computer Science and Engineering" with the prerequisite relationships in the Meta Learning Management System.

The Topics of courses will be extracted and determined from existing course outlines for the courses at UNSW.

The following image shows the course schedule in the course outline of COMP1511.

Course Schedule

Week	Lectures	Tutes	Labs	Live Streams	Assignments	Reflections
1	Course intro, Our First C Program (variables and if statements)	Welcome, What is programming?	Lab familiarization, Setting up working from home (VLAB), Basic Input/Output	-	-	
2	Problem Solving and Looping	Variables and If Statements	Variables and If Statements	-	-	Reflection 0 Due
3	Code Style, Code Reviews, Functions and Arrays	Looping	Looping	-	-	
4	Functions, Arrays, Memory and Pointers	Code Reviews, Functions and Arrays	Code Reviews, Functions and Arrays	Assignment 1 overview	Assignment 1 released	Reflection 1 Due
5	Debugging, Characters, Strings and Structs	Functions, Arrays and Pointers	Functions, Arrays and Pointers	-	-	
6	Flexibility Week. Guest Lectures, Halfway Course recap. Professionalism	No Tutorials	No Labs	-	Assignment 1 due	Reflection 2 Due
7	Memory Allocation, Multi-file projects and Linked Lists	Characters, Strings and Structs	Characters, Strings and Structs	-	-	
8	Linked Lists	Memory Allocation and Linked Lists	Memory Allocation and Linked Lists	Assignment 2 overview	Assignment 2 released	Reflection 3 Due
9	Abstract Data Types, Recursion	Linked Lists	Linked Lists	-	-	
10	Exam prep and Course recap	Abstract Data Types	Exam practice (past exam questions)	-	Assignment 2 due	Reflection 4 Due
11	Revision and study for the exam (no formal lectures)	Revision Tutorial for any that were missed due to Public Holidays	Revision Lab for any that were missed due to Public Holidays	Revision stream	-	

Figure 6.1: Course Schedule of COMP1511

Based on the course schedule in Figure 6.1, these are the Topics for COMP1511:

- Variables
- If Statements
- Looping
- Function

- Arrays
- Pointers
- Characters
- Strings
- Structs
- Memory Allocation
- Linked Lists
- Abstract Data Types
- Recursion

6.3.2 Scenario 1: Rolling Over to a New Course Offering

This scenario is about when COMP1511 (an already existing course) needs to be redelivered for a new course offering. To closely simulate an average scenario, an additional assumption will be made here:

- The new course offering will be created and delivered by the same User. This means, the User will have access to all resources relating to the course on Moodle.

Workflow Without Meta LMS

The following describes the steps taken by a User when rolling over the course *without* the use of the Meta Learning Management System:

1. Create a new course on Moodle.
2. Import from an existing course by selecting the "Import" option in settings and choosing all the items to import. That is, all the Topics and Learning Materials.

Workflow With Meta LMS

The following describes the steps taken by a User when rolling over the course *with* the use of the Meta Learning Management System:

1. Create a new course on Moodle.
2. Export a Topic that will be needed in COMP1511 as a Common Cartridge package on the Meta LMS.
3. Repeat the previous step 12 more times to export a total of 13 Topics to use for COMP1511. (This is counted as a total of 13 steps)
4. Upload a Common Cartridge package exported from the Meta LMS previously by choosing the "Restore" option in the course settings on Moodle.
5. Repeat the previous step 12 more times for each of the Common Cartridge package corresponding to a Topic. (This is counted as a total of 13 steps)

Results

After examining the above steps and performing the calculations for reusability and efficiency based on the definitions stated earlier in this chapter, the following table displays the results for comparison.

Scenario 1	**Reusability (% of resources reused)**	**Efficiency (number of steps)**
Without Meta LMS	100%	2 steps
With Meta LMS	100%	27 steps

In both workflows, 100% of the course is using existing content has been reused. However, the Meta Learning Management System is much less efficient as it is an external tool which means there are some overhead when using it. In this particular scenario of rolling over an existing course, since Moodle already provides a built-in feature to do so, using the Meta Learning Management System actually causes the process to be less efficient.

6.3.3 Scenario 2: Create a New Course with Many Overlaps

This scenario is about creating a new course COMP1911 Computing 1A which largely overlaps with existing Topics and Learning Materials (i.e. Topics in COMP1511 listed in Section 6.3.1). To closely simulate an average scenario, an additional assumption will be made here:

- The User will not have access and may not be aware of the existing course COMP1511 on the Learning Management System as COMP1511 may have been created and delivered by another User.

Before we simulate the creation of COMP1911, the Topics designed for COMP1911 have been extracted from its course outline. The following diagram shows the course schedule of COMP1911.

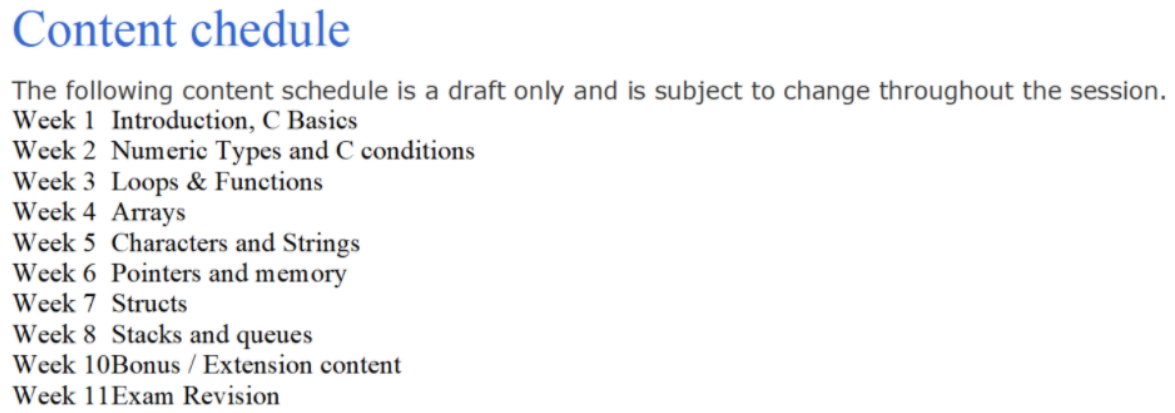

Figure 6.2: Course Schedule of COMP1911

The following Topics are extracted from the schedule and Topics which overlap with existing COMP1511 Topics have been made bold;

- **Variables** (renamed from "Numeric Types")
- **If Statements** (renamed from "C conditions")
- **Looping** (renamed from "Loops")
- **Function**

- **Arrays**
- **Characters**
- **Strings**
- **Pointers**
- **Memory Allocation** (renamed from "Memory")
- **Structs**
- **Abstract Data Types** (as a replacement for "Stacks" and "Queues")

Some Topics have been renamed based on personal understanding on the Topics from a tutor's perspective to allow for consistency and convenient comparison. Additionally, the Topics "Stacks" and "Queues" has been replaced with the Topic "Abstract Data Types" due to the differences in how granular Topics are defined in COMP1511 compared to COMP1911 as "Stacks" and "Queues" are often a subset of what is covered in "Abstract Data Types" Topic. This ambiguity in the analysis will be further discussed in Section 6.3.5.

Workflow Without Meta LMS

The following describes the steps taken by a User when creating COMP1911 *without* the use of the Meta Learning Management System:

1. Create a course on Moodle.
2. Create Learning Materials relating to the 11 different Topics of the course on the User's local disk from scratch. (This is counted as a total of 11 steps for the 11 Topics)
3. Upload Learning Materials related to each Topic of the course onto Moodle. (This is counted as a total of 11 steps for the 11 Topics)

Workflow With Meta LMS

1. Create a course on Moodle.
2. Export a Topic (as a Common Cartridge package) that will be needed in COMP1911 which exists in the Meta LMS.
3. Repeat the previous step 10 more times to export a total of 11 Topics to use for COMP1911. (This is counted as a total of 11 steps)
4. Upload a Common Cartridge package exported from the Meta LMS in the previous steps by choosing the "Restore" option in the course settings on Moodle.
5. Repeat the previous step 10 more times for each of the Common Cartridge package which corresponds to a Topic. (This is counted as a total of 11 steps)

Results

After examining the above steps and performing the calculations for reusability and efficiency based on the definitions stated earlier in this chapter, the following table displays the results for comparison.

Scenario 2	**Reusability (% of resources reused)**	**Efficiency (number of steps)**
Without Meta LMS	0%	23
With Meta LMS	100%	23

From the above table, it can be seen that by using the Meta Learning Management System, 100% of the COMP1911's content can come from reusing existing Learning Materials on the Meta LMS without any Learning Materials needed to be created from scratch. On the other hand, without the use of the Meta LMS, all content will be required to be created again.

In terms of efficiency, purely examining the numbers in the table suggests that both workflows as equivalent in efficiency. However, practically speaking, the creation of Learning Material of Topics from scratch can be quite costly in terms of the amount of time it would take. Hence, if we are assessing the two workflows with the notion of time as a factor to consider, the workflow involving the Meta LMS is more time efficient.

6.3.4 Scenario 3: Create a New Course with Few Overlaps

This scenario is about creating a new course COMP2521 Data Structures and Algorithms which has a few overlaps with existing Topics and Learning Materials (i.e. Topics in COMP1511 listed in Section 6.3.1). To closely simulate an average scenario, an additional assumption will be made here:

- The User will not have access and may not be aware of the existing course COMP1511 on the Learning Management System as COMP1511 may have been created and delivered by another User.

Before we simulate the creation of COMP2521, the Topics designed for COMP2521 have been extracted from its course outline. The following diagram shows the course schedule of COMP2521.

Course Schedule

The schedule of lecture topics (subject to change) is:

Week	Topics	Lecturer
1	Analysis of algorithms	Dr Ashesh Mahidadia
2	Recursion, Analysis of ADT (multiple) implementations, Trees	Dr Ashesh Mahidadia
3	Binary search trees (BST), Balanced search trees	Dr Ashesh Mahidadia
4	Search tree algorithms	Dr Ashesh Mahidadia
5	Graph ADT, Graph algorithms (1)	Dr Jiaojiao Jiang
6	...	
7	Graph algorithms (2)	Dr Jiaojiao Jiang
8	Sorting	Dr Jiaojiao Jiang
9	Hashing, Heaps	Dr Jiaojiao Jiang
10	Tries, Course review and review exercises	Dr Ashesh Mahidadia and Dr Jiaojiao Jiang

Figure 6.3: Course Schedule of COMP2521

The following Topics are extracted from the schedule and Topics which overlap with existing COMP1511 Topics have been made bold;

- Algorithms

- **Recursion**
- **Abstract Data Types**
- Trees
- Binary Search Trees
- Balanced Search Trees
- Search Tree Algorithms
- Graph
- Graph Algorithms
- Sorting
- Hashing
- Heaps
- Tries

Workflow Without Meta LMS

The following describes the steps taken by a User when creating COMP2521 *without* the use of the Meta Learning Management System:

1. Create a course on Moodle.
2. Create Learning Materials relating to the 13 different Topics of the course on the User's local disk from scratch. (This is counted as a total of 13 steps for the 13 Topics)
3. Upload Learning Materials related to each Topic of the course onto Moodle. (This is counted as a total of 13 steps for the 13 Topics)

Workflow With Meta LMS

1. Create a course on Moodle.
2. Export a Topic (as a Common Cartridge package) that will be needed in COMP2521 which exists in the Meta LMS.
3. Repeat the previous step 1 more time to export a total of 2 Topics to use for COMP2521. (This is counted as a total of 2 steps as there are 2 Topics which overlap with existing materials and can be exported)
4. Upload a Common Cartridge package exported from the Meta LMS in the previous steps by choosing the "Restore" option in the course settings on Moodle.
5. Repeat the previous step 1 more time for the second Common Cartridge package. (This is counted as a total of 2 steps)
6. Create Learning Materials relating to the 11 other Topics of the course on the User's local disk from scratch. (This is counted as a total of 11 steps for the 11 Topics)
7. Upload Learning Materials created from local disk related to each Topic of the course onto Moodle. (This is counted as a total of 11 steps for the 11 Topics)

Results

In this particular scenario, the workflow involving the Meta LMS has a combination of creation of content from scratch and the reuse of existing content, hence the Reusability percentage calculation is explicitly shown to prevent confusions. Using the formula described earlier for Reusability:

Reusability % =

$$\frac{2}{13} * 100 \approx 15\% \tag{6.2}$$

The following table displays the results for comparison.

Scenario 3	**Reusability (% of resources reused)**	**Efficiency (number of steps)**
Without Meta LMS	0%	27
With Meta LMS	15%	27

From the above table, it can be seen that by using the Meta Learning Management System, 15% of COMP2521's content can come from reusing existing Learning Materials on the Meta LMS due to the small overlap in Topics between the two courses. On the other hand, without the use of the Meta LMS, all content will be required to be created from scratch.

Purely examining the numbers in the table suggests that both workflows as equivalent in efficiency. However, similar to the previous scenario, the creation of content from scratch can be quite costly in terms of time taken. Hence, it may ultimately be less time efficient when creating all of the content from scratch.

6.3.5 Scenario 4: Create a New Course with No Overlaps

This scenario is about creating a new course COMP2041 Software Construction which has no overlaps with existing Topics and Learning Materials (i.e. Topics in COMP1511 listed in Section 6.3.1).

Before we simulate the creation of COMP2041, the Topics designed for COMP2041 have been extracted from its course schedule. The following diagram shows the course schedule of COMP2041.

Course Schedule

The following is a rough schedule of when topics will be covered. This will most likely change over the session as topics take more or less time to cover.

Week	Content
1	Course introduction. Unix filters.
2	Unix filters (cont'd). Shell programming.
3	Shell programming (cont'd).
4	Introduction to Version Control with Git.
5	Perl programming.
6	Flexibility week
7	Perl programming. (cont'd). **Assignment 1 due.**
8	Git in more detail
9	Tools for Performance Analysis and Deployment.
10	Revision. Exam Information. **Assignment 2 due.**

Figure 6.4: Course Schedule of COMP2041

The following Topics are extracted from the schedule;

- Unix Filters
- Shell Programming
- Git
- Perl Programming
- Performance Analysis and Deployment

Workflow Without Meta LMS

The following describes the steps taken by a User when creating COMP2041 *without* the use of the Meta Learning Management System:

1. Create a course on Moodle.

2. Create Learning Materials relating to the 5 different Topics of the course on the User's local disk from scratch. (This is counted as a total of 5 steps for the 5 Topics)
3. Upload Learning Materials related to each Topic of the course onto Moodle. (This is counted as a total of 5 steps for the 5 Topics)

Workflow With Meta LMS

The workflow would remain the same as the workflow without the Meta LMS as none of the Topics overlap with existing Topics in the Meta LMS.

Results

In this particular scenario, since the workflow with or without the use of the Meta LMS remains the same, efficiency and reusability also remains exactly the same. In short, the Meta LMS is redundant for this scenario.

6.3.6 Overall Outcome

From the above analysis of the 4 different scenarios:

- Scenario 1: Rolling Over to a New Course Offering
- Scenario 2: Create a New Course with Many Overlaps
- Scenario 3: Create a New Course with Few Overlaps
- Scenario 4: Create a New Course with No Overlaps

It can be observed that the Meta Learning System allows more content to be reused and processes to be more efficient or time efficient as less content is being created from scratch. However, most benefits of the system is only evident in scenarios where overlaps do appear and a User is trying to create a new course.

In cases where a User is rolling over to a new course offering with an existing course, since Moodle and many other Learning Management System provide in-built features that allows the easy reuse of content for this use case, trying to use the Meta LMS here would actually lead to more overhead.

In the case where there are no overlaps in the new course being created with the existing content on the Meta LMS, the system becomes redundant and provides no benefits in the short term. However, if the new content created are added to the Meta LMS, in the long term, benefits may be observed when more courses need to be created.

6.3.7 Limitations

In performing the Reusability and Efficiency analysis described in this section (Section 6.3), we have made an attempt to ensure the process is as objective and as accurate as possible. The analysis can be a good starting point and understanding the impact of the Meta LMS, but there are limitations and ambiguities in the procedures that have been difficult to address.

Some of the issues recognised include:

- **Vocabulary of Topics** - Different courses in used different terminologies to refer to possibly the same Topic.
- **Granularity of a Topic** - As Topics in this analysis have been determined purely based on the course outlines of UNSW courses, there are variation in how granular a Topic is defined. In an ideal situation, the level of granularity of Topics should be similar. An example of this is when looking at the Topics in COMP1911 of Scenario 2 compared to COMP1511. COMP1911's Topics "Stacks" and "Queues" are a subset of what may be the COMP1511's Topic of "Abstract Data Types".
- **Depth or Difficulty of a Topic** - Even when two Topics are identified as the same Topic, for example COMP1511 and COMP2521's "Abstract Data Types", it is possible they are covering the Topic to a varying level of depth.

- **Scenario Edge Cases** - There exists other cases which may not have been covered in the 4 scenarios performed. For example, if a User needs to make modifications for the Topic which they export from the Meta LMS before they can use it. This has been left out from the scenarios as it is difficult to quantify the modifications in which a User may make.
- **Efficiency Unit of Measurement** - In this analysis, Efficiency is measured by the number of steps taken. However, in simulating the workflows, it seems that the notion of time could be an essential factor in determining efficiency. Additionally, what is defined as a "step" is left ambiguous. The workflows have been broken up into "steps" by making a judgement on what "seemed sensible".
- **Assumption Being Made For Content to Already Exist** - For the analysis, assumptions that there are already content on the Meta LMS about COMP1511 is made. It does not take into account the time taken to upload the COMP1511 Topics and Learning Materials to the Meta LMS. With this kept in mind, the efficiency of the system may be lower than what has been discussed in the scenarios but the overall efficiency for all academics and course convenors may still be improved.

6.4 Feedback from Potential Users

Feedback in regards to the system have been gathered through conversations with different academics and course convenors as well as educational developers.

6.4.1 Selection of Audience

As an attempt to gather different perspectives and opinions about the system, a variety of academics and course convenors in varying roles were surveyed from different schools at UNSW, including:

- School of Computer Science and Engineering
- School of Electrical Engineering and Telecommunications

- School of Humanities & Languages
- Business School

Some of the academics and course conevenors surveyed come from UNSW Global which is affiliated with UNSW but provides foundation courses to assist students in preparing for entry into university.

Specifically, the people who were involved in the survey have been mentioned in the Acknowledgements section of the report.

6.4.2 Structure of Survey

To allow the process to be as efficient and as effective as possible, a brief introduction was given with a few questions asked prior to a demonstration. Then a short walkthrough of the Meta Learning Management System was demonstrated before academics and course convenors answered more questions.

The following outlines the questions which guided each conversations:

Questions Prior to Demonstration:

1. What Learning Management Systems do you use currently to manage your courses and course content?
2. Have you experienced or observed situations where you or another academic or course convenor had to create the same content multiple times? Is so, do you have an example?
3. Are there ways in which you have attempted to reduce duplication in the creation of content yourself?

Questions after Demonstration:

1. Does the system look easy and intuitive to use?

2. Would you use this system for helping you to build your courses in its current form? Why or why not?
3. Would this encourage you to reuse existing content on the Meta LMS, help you reduce content creation and make your processes more efficient? Why or why not?
4. Would this facilitate and encourage you to share content with other academics and course convenors?
5. Does the student process of Preparation, Content, Practice and Assessment match how you would structure content? Is it helpful to you in assisting the creation and structure of content? Why or why not?
6. Are there any particular feature(s) you would use the most if you were using this system?
7. Are there any particular feature(s) you would use the least or not use on the system?
8. What are some positive aspects of the system?
9. What are some aspects of the system which could be improved on?
10. Do you have any final comments or questions?

For educational developers, the structure of conversations had been purposefully left open and flexible to allow educational developers to more freely express their thoughts and opinions.

6.4.3 Results

As the responses have been received verbally, they will be paraphrased and summarised in this section.

Most of the surveyees, use Moodle and/or WebCMS3 as their main Learning Management System. Some with the addition of tools such as Youtube and gitlab to manage content and delivery of content.

Majority of the people surveyed, have recognised that they have either personally experienced creation of duplicate content for the same Topics across different courses or observed this happen

in other course. Some examples which had been given include duplications between UNSW's COMP1531 and COMP2511, COMP1511 and COMP1911 and so on. This issue is also observed outside of the School of Computer Science and Engineering, in particular, a course convenor from the Business School had seen and personally experienced repetition of content for example between an economics course and a personal finance course.

After demonstrating the system to the surveyees, most of them responded with that the system is easy and intuitive to use. However this needs to take into consideration that a walkthrough demonstration had been delivered before this question had been asked. Few raised the concern of the system being very dependent on some concepts such as Topics and Topic Groups which may create a steep learning curve for many new Users to the system.

Majority of the surveyees agreed that this system does encourage the the reuse of content provided that people do share and upload them on the system which seemed to be more of the concern.

Upon asking whether this would encourage the surveyees to share content with other academics and course convenors, all of them answer yes. Though, it was brought up by many that there may be Intellectual Property issues related to the sharing of content and some academics and course convenors may be reluctant to share what they have spent quite a lot of time on with others.

The response to the structure of Preparation, Content, Practice and Assessment within a Topic was quite positive with many agreeing that would follow this structure and seems quite logical. Some did express the desire to customise this structure and others identified that sometimes Learning Materials may not clearly belong to "Content" or "Practice" as an example.

In speaking about the features of the system, many seems to recognise and agree with the workflow proposed. However, concerns were raised in the cost of using the Meta LMS including the learning curve, and the cost of uploading content into the LMS. As quoted from one surveyee, "What's in it for me?". It was recognised that in the long term the benefits could be seen but many already had their own personalised workflow in the creation of the course and would be difficult to switch but if they were new to the university and need to adopt a new workflow,

they would be willing to try this.

In general, the overall feedback for the system was positive and it seems that most academics and course conevnors surveyed agreed that this system would help encourage reusability and make processes more efficient if it was fully adopted. However, the major concern in general is the transition from existing practices into this new workflow.

6.4.4 Limitations

There are some limitations due to the nature in which this survey had been conducted. In an ideal scenario, to get the most accurate feedback about the system, the audience surveyed should be given an opportunity to try and use the system first hand. However, in order to allow the process to be more efficient so that it encourages more responses from potential Users, there has been an attempt to minimise the amount of tasks the surveyee has to complete.

Chapter 7

Conclusion

As aforementioned in the Introduction, the overall aim of this thesis is *to maximise the reusability of learning content and improve the efficiency in the course creation workflow for academics and course convenors through designing and developing the Meta Learning Management System. That is, a centralised system consisting of a standardised structure for storing learning content which facilitates a more student-learning friendly structure and enables academics and course convenors to create, store, export and easily share and reuse learning content in the creation of different courses.*

This has been achieved by careful designs and implementations of a multi-dimensional Topic Graph as an attempt to closely model knowledge and learning content as modular, fine-grained Topics.

The positive impact of the implemented proof of concept on the efficiency of processes for academics and course convenors and the reusability of learning content has been demonstrated in particularly through the third step of the analysis framework in Chapter 6 where we simulate course creation scenarios. It was shown that by involving the Meta Learning Management System in an academic's workflow, when creating a new course, the reuse of content can be maximised and the efficiency of the process is improved, especially in terms of time. Additionally, the system has also been recognised by various academics and course convenors who provided feedback as shown in the final step of the analysis framework.

In summary, the main contribution of this thesis include:

- The introduction of a new workflow involving the Meta LMS for academics and course convenors in creating a course
- The design and development of a multi-dimensional network graph structure based on the notion of fine-grained Topics in representing knowledge and learning content.
- A standardised structure to facilitate academics in the organisation of learning content within a Topic based on existing models of student's learning process.
- The introduction of modular exportable Topic packages which can be combined together to form various courses for a Learning Management System used.
- Abstracting the creation and organisation of knowledge and learning content away from the creation of courses on Learning Management Systems, allowing content creation to be independent from course design and delivery.
- The development of a functioning proof of concept involving all of the above as well as other additional features which facilitate the content and course creation workflow of academics and course convenors.

7.1 Challenges

The main challenges in this thesis mostly come from defining the standardised structure of a graph for the Meta Learning Management System. Challenges and questions raised throughout this process have been discussed in Chapter 3 of this thesis. Technically, when implementing the Meta Learning Management System, the main challenge is Graph Visualisation, it has been extremely difficult to find the right tools to use for the visualisation of the designed structure due to the large number of options available and the learning curve associated with a tool that provides enough flexibility was quite high.

7.2 Future Work

Potential future works for this thesis include:

- Answering some of the question raise in Chapter 3 of this report
- Adding more dimensions to the graph representation to more closely represent the knowledge structures and processes
- Graph visualisation user experience improvements in the proof of concept
- Incorporating the notion of versioning in Learning materials for one Topic
- Allow more types of learning assets to be accepted on the Meta LMS
- Evolve into an independent system involving other stakeholders (e.g. students)

Chapter 8

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