# Integrating an LLM (Large Language Model) Tool in Post-Secondary Course Syllabus Analysis Pipeline

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**Abstract** This paper introduces a pipeline for analyzing post-secondary course syllabi, leveraging large language models (LLMs). Our approach simplifies traditional labour-intensive and technically demanding syllabi analysis. The analyzer module of this pipeline provides actionable insights, such as competency gap identification and curriculum recommendations, without requiring advanced technical expertise.

Case studies across different domains (e.g., career development, computer science, and biology education) were conducted to demonstrate the tool's ability. The results show that the tool produces analysis results that align with educational objectives and suggests improvements, highlighting its potential to streamline curriculum assessment and promote educational effectiveness.

Our future plan includes integrating this tool within Learning Management Systems (LMSs) and exploring cross-disciplinary applications to enhance the tool's utility.

## 1 Introduction

This paper introduces a new pipeline for analyzing an extensive collection of post-secondary course syllabi, capitalizing on large language models (LLM). While attempts to automatically analyze syllabi using data mining approaches have been made, the processes can be complex (e.g., collecting appropriate data, training models, and testing) and may not be readily applicable or transferable to different contexts or domains. Previous processes often require the acquisition of new datasets and retraining of models to calibrate and adjust to new contexts.

Our approach integrates an LLM tool (e.g., ChatGPT) that incorporates generic models already trained and provided by AI service providers. This allows for easy implementation and maintenance of our pipeline without the need for expert knowledge in computing and advanced analysis techniques. The tool's applications range from program and curriculum evaluations to student degree and employment consultations.

## 2 Background

Within higher education, the course syllabus remains a foundational document for communicating information, planning course structure, and motivating student success [1]. Typical elements of a syllabus include the learning outcomes, assessment criteria, course requirements, institutional-specific guidelines and resources, and class policies. Generally understood as a binding contract between instructors and students, a well-constructed syllabus will disclose expectations on the part of the teacher and the learner and establish the parameters of the course as a learning community [2].

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Beyond the contractual elements, syllabi offer a window into often hidden elements of the curriculum. Syllabi can portray philosophical dimensions of education that are often tacitly embedded throughout social and cultural norms, such as valuing different types of knowledge and learning over others [3]. Studying course syllabi provides insights into discipline-specific pedogeological trends, such as computer science [4]. Discriminatory patterns can be detected such as the underrepresentation of female scholars in political science as predicable by gender, race, age, and nationality [5]. Beyond mere administrative documents, syllabi can be seen as significant educational assets that document deeply entrenched social, cultural, and educational values and biases.

## 3 Related Work

Syllabi studies have been facilitated through various collection processes and, in many cases, but the process is often laborious an inefficient. One familiar process involves contacting course instructors and program administrators with requests for the required documentation (See [6, 7], for example). Another common practice is to find and access publicly available sources such as institutional and professional academic organizational websites (See [4]). More technical processes involve learning syllabi classification systems and applying text mining operations to established databases (see [8], for example). While the merits of syllabi studies are significant, the mining process can pose barriers by requiring steep investments of time and/or technological ability. Furthermore, the potential randomness of sampling from public sources or volunteer submissions potentially undermines the reliability of insights procured through analysis.

Multiple approaches have been used to analyze syllabi. Although technology is often used in various ways and to various degrees, the analysis outcome is guided by experts in the field with the knowledge and experience to make crucial decisions as to who to formulate the data set and glean relevant insights therefrom (see [9], for example). Expert analysis relies on established coding and pattern recognition protocols. While this method promises greater reliability on the findings, the laborious processes often involved understandably limit sample size and likely introduce problematic subjectivities. The use of advanced technologies such as text-pattern recognition alleviates some of these problems but requires extensive technological expertise to complement topic expertise (see [8], for example). Both approaches, while providing deep qualitative insights, are limited by the labour-intensive nature of manual collection and analysis, typically constraining studies to hundreds of syllabi or fewer.

The use of AI technology for syllabi studies is not new, though the recent iterations of this technology are providing new options for syllabi collection and analysis. Machine learning techniques have been used to process large quantities of syllabi in short amounts of time [10]. Early uses of machine learning focused on higher-level syllabi components such as structure and layout with less ability to navigate textual complexities (see [11], for example). More recent applications can handle linguistic complexity rather well, but still require significant pre-processing [12]. To date, leveraging AI for syllabi analysis can reduce workload but it still requires extensive expert technological and content knowledge.

## 4 Proposed Pipeline

We introduce a novel pipeline that streamlines the complex processes of syllabi analysis. It requires no expertise in specific study domains or high-level understanding of the supporting technology that is used in the system. The pipeline consists of four modules: 1) Data Preprocessing and Metadata Retrieval, 2) Knowledge Document Upload, 3) Content Analysis, and 4) Report Generation, as shown in Fig. 1. This section describes these modules in our proposed pipeline that processes course syllabi and analyzes their content to generate reports.

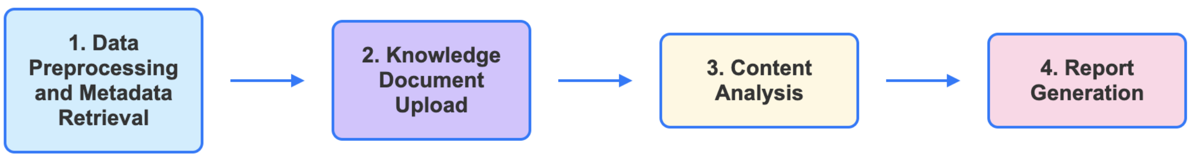


Fig. 1: Modules of the proposed pipeline for the syllabus analyzer with an LLM tool.

### 4.1 Data Preprocessing and Metadata Retrieval

This step may not be needed if all the syllabi follow the same format/template and each syllabus is contained within a single file, as the AI tools can quickly identify the template format. However, given that AI tools often limit the number of files that can be processed simultaneously, users may combine multiple syllabi into one file. Thus, it is usually crucial to preprocess the data to ensure that the desired information is easily retrievable. This can be automated by popular tools such as Adobe Acrobat and PDFtk, or a very simple script like the one shown below, which combines PDF files of each file size up to 20MB.

```bash
#!/bin/bash

# Check if input and output directories are provided
if [ "$#" -ne 2 ]; then
    echo "Usage: $0 /path/to/input_folder /path/to/output_folder"
    exit 1
fi

INPUT_DIR="$1"
OUTPUT_DIR="$2"
MAX_SIZE=$((20 * 1024 * 1024))  # Maximum file size in bytes (20MB)
CURRENT_SIZE=0
OUTPUT_COUNT=1
CURRENT_FILES=()

# Create the output directory if it doesn't exist
mkdir -p "$OUTPUT_DIR"

# Function to combine PDFs in the CURRENT_FILES array
combine_pdfs() {
    if [ "${#CURRENT_FILES[@]}" -gt 0 ]; then
        OUTPUT_FILE="$OUTPUT_DIR/combined_$OUTPUTCOUNT.pdf"
        echo "Creating $OUTPUT_FILE with ${#CURRENT_FILES[@]} files."
        gs \
            -dBATCH \
            -dNOPAUSE \
            -q \
            -sDEVICE=pdfwrite \
            -sOutputFile="$OUTPUT_FILE" \
            "${CURRENT_FILES[@]}"
        OUTPUTCOUNT=$((OUTPUTCOUNT + 1))
        CURRENT_FILES=()
        CURRENT_SIZE=0
    fi
}

# Process each PDF in the input directory
for pdf_file in "$INPUT_DIR"/*.pdf; do
    # Use stat -f%z on macOS to get file size
    FILE_SIZE=$(stat -f%z "$pdf_file")

    # Check if adding this file would exceed the max size
    if (( CURRENT_SIZE + FILE_SIZE < MAX_SIZE )); then
        CURRENT_FILES+=("$pdf_file")
        CURRENT_SIZE=$((CURRENT_SIZE + FILE_SIZE))
    else
        # Combine the current batch and start a new one
        combine_pdfs
        CURRENT_FILES+=("$pdf_file")
        CURRENT_SIZE=$FILE_SIZE
    fi
done

# Combine any remaining files in the last batch
combine_pdfs

echo "PDF combining complete. Output files saved in $OUTPUT_DIR."
```

## 4.2 Knowledge Document Upload

The next step is perhaps the most important, as the quality of the analysis heavily depends on the quality of the knowledge document to be used. In general, the knowledge document should contain the following items:

- A list of learning outcomes, learning goals, skills, and/or competencies to be developed through a course.
- A list of example activities and tasks that are said to foster the skills above and help achieve learning outcomes/goals.

### *4.2.1 Example 1: Career Development Competencies*

For example, the National Association of Colleges and Employers (NACE) [13] specifies competencies that provide a framework for understanding what skills and abilities students need in terms of career readiness to succeed in their future careers. One such competency is *critical thinking*. Information from the NACE competencies resources (among other resources) was utilized to build the knowledge document. The excerpt below shows an entry in the knowledge document for critical thinking.

**Critical Thinking**

Identify and respond to needs based upon an understanding of situational context and logical analysis of relevant information.

SAMPLE BEHAVIORS

- Make decisions and solve problems using sound, inclusive reasoning and judgment.
- Gather and analyze information from a diverse set of sources and individuals to fully understand a problem.
- Proactively anticipate needs and prioritize action steps.
- Accurately summarize and interpret data with an awareness of personal biases that may impact outcomes.
- Effectively communicate actions and rationale, recognizing the diverse perspectives and lived experiences of stakeholders.
- Multi-task well in a fast-paced environment.

TYPES OF ACTIVITIES

- Problem-solving workshops
- Data analysis and interpretation seminars
- Bias awareness and mitigation training
- Scenario-based decision-making exercises
- Diverse perspective gathering sessions
- Needs assessment and prioritization workshops
- Strategic foresight and planning activities
- Effective communication in complex situations training
- Time management and multitasking skills development
- Logical reasoning and argument analysis workshops

TYPES OF TASKS

- Analyzing complex problems from multiple angles
- Collecting and synthesizing information from diverse sources
- Identifying and challenging personal and systemic biases
- Creating decision matrices for complex choices
- Conducting stakeholder interviews and analyses
- Developing and presenting data-driven recommendations
- Practicing active listening and perspective-taking
- Creating and managing prioritized task lists
- Facilitating inclusive problem-solving sessions
- Writing clear, logical reports and presentations

Similarly, below is the entry for another competency (*technology*) from the same knowledge document:

**Technology**

Understand and leverage technologies ethically to enhance efficiencies, complete tasks, and accomplish goals.

SAMPLE BEHAVIORS

- Navigate change and be open to learning new technologies.
- Use technology to improve efficiency and productivity of their work.
- Identify appropriate technology for completing specific tasks.
- Manage technology to integrate information to support relevant, effective, and timely decision-making.
- Quickly adapt to new or unfamiliar technologies.
- Manipulate information, construct ideas, and use technology to achieve strategic goals.

TYPES OF ACTIVITIES

- Technology skills assessment workshops
- Digital literacy training sessions
- Ethical technology use seminars
- Innovation and emerging tech exploration labs
- Productivity tool mastery programs
- Data integration and analysis workshops
- Adaptive technology challenges
- Strategic technology planning sessions
- Digital problem-solving hackathons
- Tech-driven project management simulations

TYPES OF TASKS

- Evaluating and selecting appropriate software tools
- Learning and applying new digital skills
- Conducting ethical assessments of technology use
- Researching emerging technologies and their potential applications
- Optimizing workflows using productivity software
- Integrating data from multiple technological sources
- Troubleshooting and adapting to new software interfaces
- Developing technology-driven strategic plans
- Creating innovative solutions using available technologies
- Managing projects using collaborative digital tools

After uploading this knowledge document, the tool will produce a summary of the extracted skills and competencies with their corresponding activities and tasks, as shown in Fig. 2.

## Competency Summary Report

This report summarizes key competencies, associated skills, and example tasks or activities to support their development.

| Competency | Associated Skills | Example Activities/Tasks |
|---|---|---|
| Communication | Verbal, written, and non-verbal communication.<br>Active listening, persuasion, and influencing.<br>Framing communication for diverse audiences. | Delivering persuasive speeches.<br>Writing professional emails or reports.<br>Participating in non-verbal communication roleplays.<br>Analyzing cultural differences in communication styles. |
| Critical Thinking | Analyzing arguments and assessing evidence.<br>Drawing logical conclusions.<br>Solving complex problems systematically. | Conducting case study analysis.<br>Developing arguments in debates.<br>Crafting solutions for hypothetical challenges. |
| Career and Self-Development | Self-assessment and reflection.<br>Goal setting and career planning.<br>Networking and professional advocacy. | Writing personal development plans.<br>Creating LinkedIn profiles.<br>Participating in mock interviews.<br>Reflecting on career growth in journals or essays. |
| Teamwork | Collaborative problem-solving.<br>Managing group dynamics.<br>Resolving conflicts constructively. | Group projects or presentations.<br>Conflict resolution roleplays.<br>Team-building workshops. |
| Technology Application | Using technology interactively.<br>Demonstrating media literacy.<br>Implementing tools for collaboration. | Developing websites or digital portfolios.<br>Designing and delivering webinars.<br>Producing multimedia presentations. |

Fig. 2: Competencies, skills, and associated activities and tasks extracted from the NACE knowledge document.

#### *4.2.2 Example 2: Computer Science Learning Outcomes*

While the example above has an ideal format for skill/competency specifications in the knowledge document we used because it covers all the required items with much detail in an explicit format, specifications with a less strict format can still be used to generate the skills/competency summary. For example, as the knowledge documents for this module, we used three articles ([14–16]) that discuss computer science education and the competencies to be developed. The tool read and analyzed these articles and generated the summary table, shown in Fig. 3.

## Computer Science Student Competency Summary

This report summarizes the key competencies, associated skills, and example activities/tasks that students need to develop in computer science education, as extracted from the provided documents.

| Competency | Associated Skills | Example Activities/Tasks |
|---|---|---|
| System Application | Selecting and adapting user applications.<br>Performing appropriate inputs and interpreting system outputs.<br>Interactive and purposeful use of technology. | Using GUI tools to navigate software.<br>Adjusting applications for project-specific needs.<br>Identifying system failures to refine usage models. |
| System Comprehension | Understanding system structure and behavior.<br>Formulating hypotheses and testing systematically.<br>Recognizing informatics principles and their application. | Conducting Black Box and White Box tests.<br>Creating mental models of system functionality.<br>Analyzing system components and interrelations. |
| System Development | Building or reverse-engineering systems.<br>Iterative refinement using frameworks like RUP.<br>Creating and using UML diagrams for architecture modeling. | Developing prototypes to meet design requirements.<br>Writing test cases for iterative software development.<br>Simulating workflows using system design tools. |
| Non-Cognitive Skills | Teamwork and conflict resolution.<br>Empathy for diverse roles in system development.<br>Motivation and openness to continuous learning. | Role-playing user-developer scenarios.<br>Collaborating on group coding projects.<br>Participating in discussions about ethical considerations in IT. |

Fig. 3: Competencies, skills, and associated activities and tasks extracted from the three publications [14–16] that discuss computer science education and the competencies to be developed.

It should be noted that documents with incomplete or inaccurate competency specifications can result in unreliable evaluations of course syllabi. While the tool itself does not require expert knowledge, it is essential for the tool's administrators to verify the extracted specifications from the knowledge documents. Ideally, this verification process should involve consultation with domain experts to ensure accuracy and reliability before the AI tool is used for syllabus analysis.

### 4.3 Content Analysis

The core of the proposed pipeline is the content analyzer, which capitalizes on an LLM-based AI tool. It scans and analyzes several aspects of a course syllabus, such as metadata, learning outcomes, assignments, and activities, and compares them against the skill/competency specifications extracted from the knowledge documents. The analyzer also finds gaps between the desired competencies and those shown on the course syllabus and suggests potential activities/assignments that can be integrated into the course to address missing skills/competencies.

In the default setting of the analyzer, we instructed it to extract and retain the above data. However, one can also customize the analyzer to obtain other types of data that may be useful for their purposes, such as course prerequisites, textbook and reading materials, and technology requirements to take the course, as long as all the analyzed syllabi include those particular types of data.

### 4.4 Report Generation

The last module is to generate reports of the analysis results. As in the case of typical AI processes, the tool only produces raw data, and data presentation approaches can significantly influence how users can gain insights and extract necessary information from the data presented. By default, the system generates the following:

- A summary table with each course title and indicators of whether the course covers skills/competencies extracted from the knowledge documents.

- For each course, the report gives the rationale of each skill/competency covered by the course.
- If one or more skills/competencies are not addressed in the course, the report also recommends the types of activities and tasks that should be integrated into the course to address them.

A sample output of this default report format is shown in Fig. 4.

# Syllabus Analysis Report

## Summary of Skills Across Courses

| Course Title | Critical Thinking | Problem Solving | Communication | Teamwork | Technical Skills |
|---|---|---|---|---|---|
| Course 101 | ● | ● | ✖ | ● | ✖ |
| Course 202 | ● | ✖ | ● | ● | ● |

## Detailed Course Analysis

### Course 101

**Critical Thinking:** Supported through problem-based learning and case studies.

**Problem Solving:** Promoted via assignments involving practical scenarios and algorithms.

**Recommendations to Address Missing Skills**

***Communication:*** *Introduce peer review sessions or oral presentations.*

***Technical Skills:*** *Add labs focused on advanced software tools and techniques.*

### Course 202

**Critical Thinking:** Encouraged through analysis of industry-related challenges.

**Communication:** Enhanced by group presentations and collaborative writing tasks.

**Technical Skills:** Developed through hands-on coding exercises and data analysis tasks.

**Recommendations to Address Missing Skills**

***Problem Solving:*** *Suggest integrating case studies requiring iterative solution design.*

Fig. 4: An example report generated by the tool to show the course syllabi analysis.

In addition, key statistics can be exported. For example, when multiple syllabi are analyzed, the tool can generate a summary table showing how many courses cover each of the skills/competencies. Fig. 5 shows an example of this report.

## 5 Case Studies

We now examine a few examples of practical applications of this tool. In these case studies, we will show that by providing appropriate knowledge documents, one can analyze course syllabi in different major subject areas for specific purposes (e.g., career readiness).

### 5.1 Case 1: Analysis of Career Development Competencies

We will start the case studies by following up on the NACE document used in Section 4.2.1. We randomly chose several syllabi from the University of Central Florida's syllabi repository [17] and ran the analyzer based on the competency specifications shown in Fig. 2. The results of this analysis are shown in Fig. 6.

# Skills Coverage Analysis Report

## Summary of Skills Across Courses

| Skill | Number of Courses Covering |
| --- | --- |
| Interactive use of technology | 4 |
| Adapting technology to meet goals | 3 |
| System functionality exploration | 4 |
| Debugging and testing techniques | 3 |
| Building informatics systems | 3 |
| Using iterative processes for development | 2 |
| Collaboration in diverse teams | 5 |
| Empathy in user-system interactions | 4 |

Fig. 5: An example of a reporting format that shows some descriptive statistics (how many courses cover each of the skills/competencies).

# Comprehensive Syllabus Analysis Report

## Summary of Skills Across Courses

| Course Title | Communication | Critical Thinking | Career Development | Teamwork | Technology Application |
| --- | --- | --- | --- | --- | --- |
| CHM 2045C - Chemistry Fundamentals I | ● | ● | ✖ | ● | ● |
| ENC 1101 - Composition I | ● | ● | ✖ | ● | ● |
| STA 2023 - Statistical Methods I | ✖ | ● | ✖ | ✖ | ● |
| WOH 2022 - World Civilization II | ● | ● | ● | ✖ | ✖ |

## Detailed Course Analysis

### CHM 2045C - Chemistry Fundamentals I

**Communication:** Communication skills are emphasized in group activities and in-class discussions.

**Critical Thinking:** Critical thinking is developed through problem-solving activities, quizzes, and exams.

**Teamwork:** Lab collaborations and group-based problem-solving tasks enhance teamwork abilities.

**Technology Application:** Technology use is required for online quizzes and McGraw Hill virtual labs.

#### Recommendations for Missing Competencies

***Career and Self-Development:*** *Incorporate reflective assignments or career-focused discussions in chemistry fields.*

### ENC 1101 - Composition I

**Communication:** The course emphasizes written and verbal communication skills through major writing assignments and peer reviews.

**Critical Thinking:** Critical analysis of texts and rhetorical strategies are integrated into the curriculum.

**Teamwork:** Collaborative writing and group projects are incorporated to foster teamwork.

**Technology Application:** Students use ePortfolios and online writing tools.

#### Recommendations to Address Missing Skills

***Career Development:*** *Include assignments like LinkedIn profile creation or mock interviews.*

### STA 2023 - Statistical Methods I

**Critical Thinking:** Promoted via assignments solving probability problems.

**Technology Application:** Developed through software-based data visualization tasks.

#### Recommendations for Missing Competencies

***Communication:*** *Include exercises where statistical findings are explained to non-experts.*

***Teamwork:*** *Add collaborative analysis projects.*

### WOH 2022 - World Civilization II

**Communication:** Developed through essay writing and discussion forums.

**Critical Thinking:** Reinforced by analysis of historical movements and debates.

**Career Development:** Addressed by assignments requiring historical research.

#### Recommendations for Missing Competencies

***Teamwork:*** *Add group projects focused on historical timelines.*

***Technology Application:*** *Suggest use of digital tools for historical modeling.*

Fig. 6: Results of an analysis of course syllabi based on the NACE competencies.

In using this tool to analyze syllabi for NACE career development competencies, the results demonstrate the effectiveness and reliability of our proposed pipeline. The results show expected outcomes. For example, one would expect to find technology competencies in STEM courses and critical thinking competencies in humanities courses.

This tool also accurately identified competencies in less obvious places. For example, digital literacy competency is cultivated in ENC 1101, a first-year composition class that requires the creation of digital portfolios and multimedia projects, such as literacy movies and visual rhetorical analyses, showcasing students' ability to use digital tools for academic and creative purposes. It identifies critical thinking in CHEM 2045 - General Chemistry I, as students are required to solve quantitative chemistry problems, analyze experimental results, and interpret data in lab settings. These activities demand higher-order thinking and the ability to evaluate evidence and apply scientific principles.

The suggested modifications to enhance NACE competencies are appropriate to the course topic and discipline. On one hand, it may encourage minor course modifications, such as the introduction of small group projects for a psychology course to foster teamwork and leadership skills. On the other hand, it may prompt instructors to make such work visible within the context of career-readiness competencies and transferable skills. Collaborative assignments in a physics course are not novel and, indeed, are likely already taking place. The recommendation offered by the AI tool may merely encourage the highlighting of these types of activities.

Overall, the results show strong alignment with expected educational outcomes, providing validation for both the tool's analytical capabilities and its practical utility in curriculum assessment.

### 5.2 Case 2: Analysis in Computer Science Education

In this example, we will capitalize on the extracted learning outcomes for computer science programs discussed in Section 4.2.2 (the corresponding analysis of knowledge documents is shown in Fig. 3) and run the analyzer on several computer science course syllabi from Saint Mary's University. The results are shown in Fig. 7.

The results are reasonable based on the contents of the syllabi. For example, CSCI 1226 and CSCI 1227 are first-year computer programming language courses in Java and Python, respectively, focusing on fundamental programming concepts. They tend to focus less on team and collaborative aspects of system development, which often requires higher programming skills. This resulted in a missed competency of "Non-Cognitive Skills" with associated skills of teamwork and conflict resolution, empathy for diverse roles in system development, and motivation and openness to continuous learning. One interesting difference between the results for these courses was seen in "System Comprehension." This was likely because the CSCI 1226 syllabus stated "a high-level view of the components of a computing system" as one of the topics to be covered, while the CSCI 1227 syllabus did not explicitly mention such related topics.

CSCI 3475 is a course on Human-Computer Interaction that covers theories and methodologies of common user-centred design approaches. The class focuses on the front-end design processes of a system with hands-on learning activities to go through various design processes, but students do not work on system development or coding. The results of the analysis accurately reflected this pedagogical approach.

CSCI 3826 course covers a wide variety of multimedia computing topics, focusing on theories/algorithms and coding/programming of various multimedia computing algorithms. Assignments are individually completed, and thus, there was no mention of group work in the syllabus. However, students were encouraged to write the two midterm examinations with their peers, which actually contributes to fostering the missing competency ("Non-Cognitive Skills"). This illustrates the accuracy of the analysis and suggests a potential revision of the syllabus to include more details of how the examinations would be conducted.

# Syllabus Analysis Report

## Summary of Skills Across Courses

| Course Title | System Application | System Comprehension | System Development | Non-Cognitive Skills |
|---|---|---|---|---|
| CSCI - 1226 Introduction to Computing Science and Programming 1226 | ● | ● | ● | ✘ |
| CSCI 1227- 1227 Computer Programming and Problem Solving | ● | ✘ | ● | ✘ |
| CSCI 3475 - 3475 Human-Computer Interaction | ● | ● | ✘ | ● |
| CSCI 3826 - 3826 Multimedia Computing and Applications | ● | ● | ● | ✘ |

## Detailed Course Analysis

### CSCI - 1226 Introduction to Computing Science and Programming

**System Application:** Demonstrated through programming tasks using Java, such as algorithm implementation and input/output tasks.

**System Comprehension:** Supported through assignments and lectures focusing on system components like memory and processors.

**System Development:** Reinforced through problem-solving and step-wise refinement in assignments.

**Recommendations**

***Non-Cognitive Skills:*** *Consider group-based coding projects to promote collaboration and empathy.*

### CSCI - 1227 Computer Programming and Problem Solving

**System Application:** Basic programming exercises highlight this competency.

**System Development:** Concepts like iteration and recursion solidify development skills.

**Recommendations**

***System Comprehension:*** *Add activities that analyze system architecture to bridge gaps.*

***Non-Cognitive Skills:*** *Include reflection assignments or peer mentoring tasks.*

### CSCI - 3475 Human-Computer Interaction

**System Application:** Activities focus on tools for UI/UX design, such as prototyping and user-testing.

**System Comprehension:** Covered via user-analysis and heuristic evaluations.

**Recommendations**

***System Development:*** *Suggest including coding components for developing interactive systems.*

### CSCI - 3826 Multimedia Computing and Applications

**System Application:** Enabled through hands-on Python-based multimedia exercises (image/video processing).

**System Comprehension:** Covered via concepts like multimedia compression and representation.

**System Development:** Projects on multimedia system design provide practical exposure.

**Recommendations**

***Non-Cognitive Skills:*** *Incorporate peer-review tasks or team projects for fostering teamwork.*

Fig. 7: Results of an analysis of computer science course syllabi based on the learning outcomes/competencies extracted from the three publications.

### 5.3 Case 3: Key Competencies in Biology Education

Finally, in this example, we will show that the analysis can be conducted without expert domain knowledge of the study subject. The authors' expertise is in Interdisciplinary Studies and Computing Science, and they have a limited understanding of biology education. We first extracted the skills/competencies by using the Oregon State University's Biology Department website [18], as shown in Fig. 8 as this analysis's knowledge document.

We then ran a content analysis on course syllabi that were publicly available from University of South Florida's website [19]. As seen in the results shown in Fig. 9, in addition to the rationales ("De-

**Biology Major Competency Summary**

This report summarizes key competencies, associated skills, and example activities/tasks outlined in the Biology Major Learning Outcomes document.

| Competency | Associated Skills | Example Activities/Tasks |
|---|---|---|
| Content Knowledge | Biochemistry, Cell and Molecular Biology, Genetics.<br>Physiology and Organismal Biology.<br>Ecology and Evolution. | Explaining molecular mechanisms of diseases.<br>Conducting dissections to study organismal biology.<br>Analyzing population dynamics in an ecological study. |
| Scientific Process | Identifying and accessing scientific information.<br>Formulating testable hypotheses and measurable predictions.<br>Designing experiments and collecting data.<br>Analyzing and interpreting scientific data. | Conducting literature reviews.<br>Designing and running controlled experiments.<br>Using statistical tools to analyze collected data.<br>Writing conclusions based on experimental findings. |
| Communication | Effective written, oral, and graphical communication.<br>Adapting information for scientific and non-scientific audiences.<br>Developing multimedia presentations. | Creating research posters for symposiums.<br>Writing scientific articles or reports.<br>Presenting research findings to diverse audiences. |
| Critical Thinking | Synthesizing information across scales and disciplines.<br>Evaluating uncertainty, assumptions, and biases in research.<br>Assessing alternative hypotheses or interpretations. | Developing interdisciplinary research proposals.<br>Analyzing conflicting results from different studies.<br>Writing critiques of published research articles. |
| Societal Relevance | Justifying the importance of science for society.<br>Integrating biology with other disciplines in decision-making.<br>Assessing societal biases and their impact on science. | Writing essays on science's role in global issues.<br>Debating ethical dilemmas in biotechnology.<br>Conducting workshops on societal impacts of research. |
| Professionalism | Understanding ethical standards in science.<br>Collaborating effectively in professional settings.<br>Engaging in career planning and self-assessment. | Participating in mock job interviews.<br>Developing personal codes of ethics.<br>Collaborating on research projects with diverse teams. |

Fig. 8: Competencies, skills, and associate activities and tasks extracted from Oregon State University's Biology Department's website.

tailed Course Analysis") of why these courses were analyzed to support/foster sets of learning outcomes, the analyzer also recommended ("Recommendations to Address Missing Skills") to consider adding two activities/assignments ("collaborative projects or ethical discussions that encourage teamwork and professional behavior") to address the missing learning outcome in BSC 1005 course ("Professionalism"), and one activity ("discussions on the impact of research on society and potential ethical dilemmas") to address the missing learning outcome in BSC 3453 course ("Societal Relevance").

While the accuracy of the analyses, including the competency analysis, cannot be verified without further expert consultation, the AI analyzer can still be utilized to easily produce insightful syllabi analysis results without expert domain knowledge.

## 6 Conclusion and Future Work

In this paper, we introduced a new pipeline that leverages large language models (LLMs) to analyze post-secondary course syllabi, offering a more accessible and flexible approach compared to traditional data mining methods. The pipeline consists of four key modules - data preprocessing, knowledge document upload, content analysis, and report generation - with the quality of analysis being heavily dependent on the comprehensiveness of uploaded knowledge documents. This tool enables various stakeholders to efficiently analyze course content, identify competency gaps, and generate recommendations without requiring extensive technical expertise or manual data processing.

The potential applications of this tool are diverse and far-reaching. At a programmatic level, it can provide broad curriculum overviews, helping identify overlaps and gaps across course selections. It can facilitate the mapping of curricula to program objectives, ensuring educational goals are being met. Additionally, the tool can assist in assessing course materials for diversity and accessibility, exploring workload distribution across similar course levels, and evaluating course equivalencies for students transferring between institutions. These are just a few potential use cases.

This pipeline offers an automation protocol for institutional work that typically requires time-consuming and arduous work by faculty and staff with deep expertise. While not suggested as a definitive assessment tool, its accessibility to users with limited subject matter and/or AI expertise makes it a valuable resource for educational institutions.

The effectiveness of this tool is also contingent upon the comprehensiveness of its training materials the quality of the syllabi being analyzed. More thorough and accurate knowledge documents yield more reliable results. While the tool cannot guarantee a complete reflection of all queried elements, its ability to provide quick, structured insights can support educational institutions in making more informed decisions about course design and program development, ultimately contributing to more effective and cohesive academic offerings.

Several promising directions could extend this research and enhance the tool's capabilities. Integration with Learning Management Systems could enable real-time syllabus analysis and feedback, while the

## Biology Syllabus Analysis Report

### Summary of Skills Across Courses

| Course Title | Content Knowledge | Scientific Process | Communication | Critical Thinking | Societal Relevance | Professionalism |
|---|---|---|---|---|---|---|
| BSC 1005 - Biological Principles for Non-Majors | ● | ● | ● | ● | ✖ | ✖ |
| BSC 2011 - Biological Diversity | ● | ● | ✖ | ● | ● | ✖ |
| BSC 2011L - Biodiversity Lab | ● | ● | ● | ● | ✖ | ✖ |
| BSC 3453 - Research Methods in Biological Sciences | ✖ | ● | ● | ● | ✖ | ● |

### Detailed Course Analysis

#### BSC 1005 - Biological Principles for Non-Majors

**Content Knowledge:** Focuses on cell biology, evolution, genetics, and biodiversity.

**Scientific Process:** Incorporates the scientific method and experimental analysis.

**Communication:** Assignments include presentations and written reports.

**Critical Thinking:** Promotes understanding of macromolecules and metabolic pathways.

**Recommendations for Missing Competencies**

***Societal Relevance:*** *Add modules on the impact of biotechnology on society.*

***Professionalism:*** *Include ethics discussions related to biological research.*

#### BSC 2011 - Biological Diversity

**Content Knowledge:** Covers taxonomy, evolutionary theory, and biodiversity among major taxa.

**Scientific Process:** Emphasizes hypothesis-driven studies and evolutionary modeling.

**Critical Thinking:** Develops understanding of species interactions and adaptations.

**Societal Relevance:** Highlights biodiversity conservation and societal impacts of extinction.

**Recommendations for Missing Competencies**

***Communication:*** *Integrate oral presentations and collaborative group projects.*

#### BSC 2011L - Biodiversity Lab

**Content Knowledge:** Practical exercises in taxonomy and organismal classification.

**Scientific Process:** Students engage in hypothesis-driven labs and experimental design.

**Communication:** Lab reports and group discussions emphasize scientific reporting.

**Critical Thinking:** Encourages analysis of experimental outcomes and alternative explanations.

#### BSC 3453 - Research Methods in Biological Sciences

**Scientific Process:** Students learn experimental design, sampling, and statistical analysis.

**Communication:** Focus on presenting research findings in written and oral formats.

**Critical Thinking:** Evaluates biases and logical reasoning in biological studies.

**Professionalism:** Emphasizes ethical research practices and scientific professionalism.

Fig. 9: Results of an analysis of four biology course syllabi based on the Key Competencies in Biology Education, extracted from Oregon State University's Biology Department's website.

development of standardized knowledge document templates could improve analysis consistency across different institutions. The tool could be expanded to analyze student learning outcomes across different institutions and countries, incorporating machine learning components that improve accuracy based on user feedback. Future iterations could include features to analyze temporal changes in curriculum, integrate Diversity, Equity, and Inclusion metrics, and develop discipline-specific analysis modules that account for unique field requirements. Additional enhancements could include automated syllabus formatting tools to improve preprocessing accuracy, cross-language analysis capabilities for international education contexts, and integration with career pathway mapping tools to better align course content with industry requirements. These developments would strengthen the tool's utility in supporting curriculum development, program assessment, and student success initiatives across diverse educational contexts.

We are currently investigating how this system performs in the domain of Interdisciplinary Studies (IDS) education. IDS education requires multiple core competencies, creating a unique study case for this analyzer. We will also compare the results from this analyzer against our former study on the syllabi analysis [7] and utilize the results to inform the IDS curriculum.

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## References

Harrington C, Thomas M (2018) *Designing A Motivational Syllabus: Creating a Learning Path for Student Engagement*. First Web Routledge, Oxford

Richmond AS, Morgan RK, Slattery JM, Mitchell NG, Cooper AG (2019) Project Syllabus: An Exploratory Study of Learner-Centered Syllabi. *Teaching of Psychology* 46(1): 6–15

Rocha SD (May 2023) The Syllabus as Curriculum: A Reconceptualist Approach. *Philosophical Inquiry in Education* 30(1): 80–83

Fiesler C, Garrett N, Beard N (2020) "What Do We Teach When We Teach Tech Ethics?: A Syllabi Analysis" *Proceedings of the 51st ACM Technical Symposium on Computer Science Education* Web ACM, New York, NY, USA: 289–295

Smith A, Hardt H, Meister P, Kim H (2020) Gender, Race, Age, and National Origin Predict Whether Faculty Assign Female-Authored Readings in Graduate Syllabi. *PS: Political Science & Politics* 53(1): 100–106

Dubicki E (2019) Mapping curriculum learning outcomes to ACRL's Framework threshold concepts: A syllabus study. *The Journal of Academic Librarianship* 45(3): 288–298

Akiyama Y, Woodill S (June 2022) "What Interdisciplinarians Teach: Syllabi Analysis of Post-Secondary Courses in Interdisciplinary Studies" *Proceedings of The 12th Canada International Conference on Education (CICE-2022)* Toronto, Canada

Yasukawa M, Yokouchi H, Yamazaki K (2020) Syllabus Mining for Analysis of Searchable Information. *International Journal of Institutional Research and Management* 4(1): 46–65

Butler K, Calcagno T (2020) Syllabus Mining for Information Literacy Instruction: A Scoping Review. *Evidence Based Library and Information Practice* 15(4): 83–104

Yang T-C (2023) Application of Artificial Intelligence Techniques in Analysis and Assessment of Digital Competence in University Courses. *Educational Technology & Society* 26(1): 232–243

Smolin D, Butakov S (2012) "Applying Artificial Intelligence to the Educational Data: An Example of Syllabus Quality Analysis" *Proceedings of the 2nd International Conference on Learning Analytics and Knowledge*: 164–169

Fan Z, Chiong R (2023) Identifying Digital Capabilities in University Courses: An Automated Machine Learning Approach. *Education and Information Technologies* 28(4): 3937–3952

*National Association of Colleges and Employers.* (2024) `https://www.naceweb.org/` Accessed: Dec 4, 2024

Kollee C, Magenheim J, Nelles W, Rhode T, Schaper N, Schubert S, Stechert P (Jan. 2009) Computer Science Education and Key Competencies.:

Zendler A, Seitz C, Klaudt D (Jan. 2016) Process-Based Development of Competence Models to Computer Science Education. *Journal of Educational Computing Research* 54(4) Pädagogische Hochschule Ludwigsburg:

Bender E, Hubwieser P, Schaper N, Margaritis M, Berges M, Ohrndorf L, Magenheim J, Schubert S (2015) Towards a Competency Model for Teaching Computer Science. *Peabody Journal of Education* 90(4): 519–532

University of Central Florida (2024) *Syllabus Library.* `https://ucf.simplesyllabus.com/en-US/syllabus-library` Accessed: Dec 4, 2024

Oregon State University (2024) *Biology Major Learning Outcomes.* `https://ib.oregonstate.edu/undergraduate/majors-minors-options/biology-major/learning-outcomes` Accessed: Dec 4, 2024

University of South Florida Sarasota-Manatee (2024) *Course Syllabi Archive.* `https://www.sarasotamanatee.usf.edu/academics/course-syllabi-archive.aspx` Accessed: Dec 4, 2024