Assessing a combined human coding and natural language processing method for qualitative analysis in physics education research

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INTRODUCTION & LITERATURE REVIEW

- AI tools, including NLP, are increasingly being used in education research & PER [1-7]
  - <u>These tools must be tested carefully using manageable datasets</u>
    - Syllabi are easy to obtain and offer rich instructional insight [8]
- NLP on modern physics syllabi showed AI could cross-validate human identified topics and policies but undercounted topic frequency compared to human coding [1]
- This study analyzes syllabi from 50 US physics programs across the entirety of the four-year QM curriculum

METHODS

- BERTopic, a topic modeling algorithm, was used to identify latent themes in syllabi
  - tokenizing text, generating embeddings, reducing dimensionality, and clustering similar text segments into topics
- 121 syllabi were used from a previous study [9]
  - 50 US physics departments entire undergrad QM curriculum syllabi collected
    - 18.5% physics bachelors in 2021-2022
    - 84% very high research activity
    - 70% public
    - 14% MSI

Combined Freq.	Interpretation	Individual Freq.	Topics Identified by BERTopic	Representative Example Phrase
45 (90%)	Textbook	37	textbook, textbooks, lectures, lecture, reading, classroom, books, reading, lecturing, sections	“Readings since lecture activities will consist of the students working individually or in groups...”
		36	quantum, textbook, books, textbooks, introductory, book, introduction, griffiths, library, isbn	“Textbook introduction to quantum mechanics by David J Griffiths...”
		28	textbooks, textbook, books, fundamentals, texts, tiplermodernphysicssec, library, isbn, book, wiley	“[redacted] version page required texts materials Modern Physics for Scientists and Engineers nd edition...”
		11	feynman, lectures, books, book, topics, lecture, [redacted], quantum, physics, library	"Other books that may be of interest...”
		6	wileyplus, wiley, textbook, bookstore, registration, assignments, pdf, [redacted], edition, purchasing	“If the new textbook does not come with a WileyPlus registration...”

Human Analysis			AI Analysis		
Human coded topics	Freq. (%)	Combined freq. (%)	Freq. (%)	Ten most relevant words	Human interpretation
3D quantum mechanics	94	98	42	spin, spinors, rotations, rotational, orbital, angular, gyromegnetic, rotate, momenta, proton	Spin
Spin	76				
Formalism	78	78	40	eigenfunctions, hermitian, observables, operators, observable, eigenstates, operator, unitary, hermicity, hermite	Formalism
Schrodinger equation	98	100	40	potentials, scattering, wells, quantummechanical, harmonic, tunneling, potential, particle, tunnelling, amplitude	Tunneling
Tunneling	70				
Particles	70				
Not identified			40	topics, relativity, particles, schrodinger, atomic, particle, [redacted], cosmology, matter, waves	Modern physics topics
Not identified			36	relativity, relativistic, lorentz, einstein, dilation, spacetime, clocks, morley, velocity, frames	Modern physics topics
Schrodinger equation	98	100	36	schrodinger, quantum, solutions, dimensional, potentials, dimension, wave, equation, schrodinger, threedimensional	Schrodinger equation
Wave functions	74				
3D quantum mechanics	94				

RESULTS

- BERTopic identified 70 topics
  - Human supervision grouped redundant topics
- BERTopic generated 14 course content topics
- Most frequent topics:

Common words	90%
Textbook	90%
Exam/quizzes	88%
Assignment submission	88%
Grading policy	86%
Academic misconduct	82%
Course preliminaries	82%
Accomodations	78%
Attendance	68%
Learning goals	66%

DISCUSSION & CONCLUSION

- AI topics appear less frequently than human-coded ones
- 13 out of 14 BERTopic content topics were coherent human interpreted themes
- AI generated 3 topics that fell outside intended scope of study
- Despite differences in frequency and theme alignment, BERTopic produced coherent and relevant quantum topics
  - though still requiring human supervision & refinement

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