

How to quantify an examination? Evidence from physics examinations via complex networks

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Given the untapped potential for continuous improvement of examinations, quantitative investigations of examinations could guide efforts to considerably improve learning efficiency and evaluation and thus greatly help both learners and educators. However, there is a general lack of quantitative methods for investigating examinations. To address this gap, we propose a new metric via complex networks; i.e., the knowledge point network (KPN) of an examination is constructed by representing the knowledge points (concepts, laws, etc.) as nodes and adding links when these points appear in the same question. Then, the topological quantities of KPNs, such as degree, centrality, and community, can be employed to systematically explore the structural properties and evolution of examinations. In this work, 35 physics examinations from the Chinese National College Entrance Examination spanning from 2006 to 2020 were investigated as an evidence. We found that the constructed KPNs are scale-free networks that show strong assortativity and small-world effects in most cases. The communities within the KPNs are obvious, and the key nodes are mainly related to mechanics and electromagnetism. Different question types are related to specific knowledge points, leading to noticeable structural variations in KPNs. Moreover, changes in the KPN topology between examinations administered in different years may offer insights guiding college entrance examination reforms. Based on topological quantities such as the average degree, network density, average clustering coefficient, and network transitivity, the comprehensive difficulty coefficient is proposed to evaluate examination difficulty. All the above results show that our approach can objectively and comprehensively quantify the knowledge structures and examination characteristics. These networks may elucidate comprehensive examination knowledge graphs for educators and guide adjustments and improvements in teaching methodologies.

Primary author: XIA, Min

Co-authors: Mr SU, Zhu; Mr DENG, Wei-Bing; Prof. FENG, Xiu-Mei; ZHANG, Ben-Wei (Central China Normal University)

Presenter: XIA, Min

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