The Complex Linear Logistic Test Model (LLTM, Fischer, 1973) o As the extended Rasch model, the LLTM was developed to incorporate item content features or other item properties to help predict success on a particular item, by decomposing the item difficulty parameter of the Rasch model into a linear combination of elementary components related to the item contents.

o The LLTM functions as a testing tool for hypothesized constructs in item generation, as well as a validation tool for elementary components of items, often referred to as cognitive operations or item properties.

o It can be used effectively for psychometric studies on measuring the effect of various testing conditions such as item presentation position, content-specific learning, speeded item presentation, and item response format as well as measurement of changes. (Kalibup, 2009).

Motivation of this study o The LLTM was traditionally used for examining the effect of cognitive operations, the rater effects, and the hypothesized construction rationales, whereas less often used for the testing contexts such as item response format, content-specific learning, and knowledge structures.

o The LLTM was originally developed for dichotomous data by extending the simple Rasch model. Studies of its use with polytomous items are comparatively less common, even if dichotomous items are used. The Carbon Cycle items are polytomous, and newly developed with specific item properties including content-specific learnings and item response format.

Research Questions
1. Which configuration of the LLTM for polytomous items fits the Carbon Cycle data the most? And, can we hold that model compared to the PCM and the RSM?
2. Using the LLTM, what is the contribution of each item property to the overall item difficulty of the Carbon Cycle items? Is this intuitively compatible with how did this help us understand how the Carbon Cycle test works?

LLTM under MRCM framework

- The Partial Credit Model (PCM) is the most general Rasch model for polytomous data, and it has a series of submodels in which certain restrictions are imposed on the item parameter.

\[ P_i(y_0 - 1) = \exp(-(\theta_i - b_k)) / (1 + \exp(-(\theta_i - b_k))) \]

- When setting the item parameter to have constant distance between any two categories across all items, this is the Rating Scale Model (RSM).

\[ \kappa = \beta_i \]

- The LLTM for polytomous items, also called as the Linear Partial Credit Model (LPCM, Fischer & Ponocny, 1994), postulates the item parameter as a linear combination of item properties. This kind of idea was specified and published earlier by Linacre (1989) as the Multifaceted Rasch model.

\[ \kappa = \sum \beta_i \notag \]

Multidimensional Random Coefficients Multinomial Logit (MRCM, Adams, Wilson, & Wang, 1997) model

- The MRCM is a very general form with the inherited fundamental measurement model of the Rasch family models, covering the ordinary Rasch model, the Logistic Regression model, the Latent Trait model, and the Logit model for polytomous items, and Multidimensional item response models.

- As the best fitting configuration of the LLTM for Polytomous items, the complex LLTM with the three categories of each item property serve as the reference models. This model was finally developed as the Multidimensional Random Coefficients Multinomial Logit (MRCM) model.

\[ \text{MRCM} = \sum \omega_i \times \text{PCM} \]

Construction of Carbon Cycle items

- Item properties and Reconstructing the LLTM

\[ \omega_i \times \text{PCM} \]

- The Carbon Cycle items are developed to ask students to answer forced choice questions and explain their choices, and their responses are scored on valid credits by scoring rubrics matching with the levels on the basis of the construct of the Carbon Cycle test.

- The items can be reconstructed by combining the three item properties: (1) Process property is about the biogeochemical process of carbon cycling. (2) Progress property is about the progress variable in which carbon cycling processes, (3) Format property is about the item response format.

- The sub-categories of each item property serve as specific predictors with a potential hypothesized effect on the item difficulty, e.g. the item 01 (BODYTEMP) has predictors of cellular respiration process, energy progress process, and multiple choice item format.

- As the best fitting configuration of the LLTM, as shown below.

\[ \text{MRCM} = \sum \omega_i \times \text{PCM} \]

Results

Simple and Complex configurations of the LLTM

- Compared with the simple LLTM without interactions of the item properties as a baseline model, the complex LLTM with an interaction between the Process and Progress item properties was finally developed as the best fitting configuration of the LLTM, as shown below.

- For practical interpretation of the item property effects, the overall item difficulty across the steps can be stated as: \( \text{Process} \times \text{Progress} \times \text{Format} \), \( \text{Process} \times \text{Progress} \), \( \text{Process} \) only, \( \text{Progress} \) only, \( \text{Format} \) only.

- Comparison of Model Fit

\[ \text{MRCM} \]

- In terms of AIC and BIC, the PCM was the best, while the simple LLTM was the worst. The complex LLTM was clearly superior to the simple LLTM.

- The LR test showed that the complex LLTM fits the data much better than the simple one (p < .001), but not as well as the PCM (p < .001).

Analysis Procedure

Sample and Data Analysis

1. 1,157 students and 13 polytomous items with the three item properties were used finally in the analyses.

2. First, the PCM and the RSM were fitted to the data as the reference models. Next, the LLTM with simple linear combination of item properties were fitted as the baseline model. In order to find the best fitting complex LLTM, several configurations of the LLTM were compared by hierarchical model comparison.

3. For model comparison, the AIC and BIC were reported, and the Likelihood Ratio (LR) test was used for nested models. Graphical model checks were conducted to see whether there is a graphical agreement of the estimates.

4. ConQuest 3.0 software was used for all analyses of fitting the MRCM models.

Reference


Conclusion and Discussion

- Although the LLTM for polytomous items fitted the data well in the PCM and the RSM in a statistical sense, it could explain how three item properties of the Carbon Cycle test affect the overall item difficulty in a substantive meaning corresponding to the Carbon Cycle construction. A practical explanation for item property effects is at the cost of a lower goodness-of-fit.

- We can say it has a large effect size in methodological foundations of item development and substantive interpretation aspects.

- Future studies couldn’t address only the value of a random-effects version of the LLTM extended with consideration of random item variation, but also multidimensional extensions of the LLTM such as the Random-Weights Linear Logistic Test Model.