A diagnostic classification model of college instructors' value beliefs towards open educational resources

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Abstract

Open educational resources (OER) can be cost-effective alternatives to traditional textbooks for higher education faculty to decrease student spending on textbooks. To further advocate college instructors' use of OER, understanding their value belief towards integrating OER in teaching is necessary but currently absent. This study thus analyzed 513 college instructors' value beliefs about using OER in college teaching by applying a psychometric model known as diagnostic classification models (DCMs). The findings of this study validated the three constructs in value beliefs measured by an OER user survey: engaging students, customizing classroom materials and supporting personal professional development. The results showed that a considerable number of college instructors maintained a low level of value beliefs towards using OER. We further provided individualized classification for each college instructor in terms of the three types of value beliefs. In addition, this study investigated how pre-determined latent classes of value beliefs influenced college instructors' practice and perception of using OER. Particularly, college instructors who value OER to address their profession needs are more likely to adapt OER in their teaching rather than merely reusing existing copies. Practical implications of supporting higher education faculty's use of OER are discussed in the end.

Keywords Diagnostic classification models · Open Educational Resources · Value belief · College instructor · Professional development

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1 Introduction

Reducing the educational cost for college students has been critical, especially during the uncertainty and societal turmoil resulting from the COVID-19 pandemic. In the United States, college students on average have to pay off up to $34,200 student loan debt upon graduation, adding up to over $1.5 trillion nationwide student loans (Zhang et al., 2020). Lower socioeconomic families may benefit from student loans, but research has indicated that inflating student loans have enlarged rather than decreased the equity gaps in education (Freeman et al., 2022; Read et al., 2020). Besides high tuition rates, college students spend increasing expenditures on textbooks and other supplemental learning materials, but those who cannot afford such high costs may not have an effective learning experience.

Open educational resources (OER) have become an alternative to costly textbooks in college instructions. OER are free, open-licensed online educational resources that allow users to retain, reuse, revise, remix and redistribute their desired resources (Hilton, 2016; Wiley, 2021). Compared to traditional textbooks, OER allow college instructors to taper off or even totally eliminate students' expenditures for textbooks and other course materials (Hendricks et al., 2017; Read et al., 2020). For example, Hendricks et al. (2017) indicated that adopting OER in a Canadian college-level physics course helped enrolled students save up to $85,000 (Canadian dollars) compared to those who took the course previously. Moreover, the decline in students' spending is not at the expense of learning effectiveness. Colvard et al., (2018) reported students' final grades were significantly higher in eight undergraduate courses that adopted OpenStax textbooks than those in prior offerings.

Advocating college instructors' use of OER in teaching may combat the rise of educational costs. Research has indicated that college instructors' decision to integrate technology was influenced by their value belief - the belief of the perceived value that technology can add to their teaching (Ottenbriet-Leftwich et al., 2010; Vongkulluksn et al., 2018). Instructors who believe technology is valuable to their professional needs (e.g., customizing course materials, supporting their professional development), and student needs (e.g., engaging students) are more likely to integrate technology (Bice & Tang, 2022; Ottenbriet-Leftwich et al., 2010) and overcome barriers of using technology (Ertmer et al., 2012; Tang, 2021a; Vongkulluksn et al., 2018). Thus, understanding factors influencing instructors' intention and practice of integrating OER in teaching is necessary but scarce.

Despite a lack of empirical evidence for college instructors' value beliefs about using OER, research has endorsed the potential of OER for addressing instructors' professional needs and assisting them in assuring student needs. Doi et al., (2022) integrated OER in their emergent remote teaching to customize course resources and address an unforeseen increase in student need for online lecture videos. In regard to instructors' professional needs, using OER to deliver professional development for college faculty and staff also broadens access, evokes unintentional mentoring rapport, and reinforces the effectiveness (Bossu et al., 2017; Slapak-Barski et al., 2014). However, instructors also voiced concerns about the barriers that they encountered when using OER such as a shortage of relevant OER and insufficient time in searching and curating OER in their practice of using OER (Jung et al., 2017; Tang et al.,

2020, 2021). Instructors' concerns about the extra time spent in customizing OER in comparison to its limited value added to their courses are voiced, which further leads to a decrease in their intention of using OER (Jung et al., 2017). To this end, a comprehensive understanding of college instructors' beliefs about the values that OER bring to their teaching is needed.

The purpose of this exploratory study was a part of the effort to fill the gap by investigating the value belief of those college instructors who integrated OER in their courses and identifying factors that influenced their value belief. Specifically, the study sought to answer two research questions (RQ).

RQ1: What are college instructors' value beliefs about integrating OER in teaching?

RQ2: What is the influence of instructors' value belief on their practices of using OER in teaching?

To address the first research question, we applied Diagnostic Classification Models (DCMs; Rupp et al., 2010; von Davier & Lee, 2019) to investigate college instructors' value beliefs about using OER. DCMs are a class of psychometric models that aim to provide multidimensional diagnostic information to test or survey respondents, "in situations where multivariate classifications of respondents are made on the basis of multiple postulated latent skills" (Rupp & Templing, 2008, p.219). Specifically, DCMs provide a more reliable measure of whether respondents have obtained certain skills or possessed any traits, compared to manually assigning a cut-off score (e.g., GPA -90 out of 100 points for an A) to determine whether respondents have shown evidence of skills or traits (Rupp et al., 2010; von Davier & Lee, 2019). In this study, we followed the value belief framework by Ottenbriet-Leftwich et al. (2010) and identified three latent subscales such as customizing course materials, supporting professional development, and engaging students. DCMs can then diagnose whether college instructors possess a certain type of value beliefs, and if so, identify the level (e.g, low, moderate or high) of belief that using OER is valuable to each subscale. To address the second research question, we applied multinomial logistic regression and analysis of variance (ANOVA) to investigate whether any differences in college instructors' value beliefs predicted college instructors' usage of OER. To this end, this study aimed to make practical recommendations on professional support provided for college instructors to raise their value belief and enhance their intention of using OER in their teaching practices.

2 Literature review

2.1 Open educational resources

Open Educational Resources (OER) allow instructors to customize and reproduce openly licensed educational materials at no cost in order to satisfy students' personalized needs (Tang, 2021b; Hilton, 2016). Particularly, instructors can retain, reuse, revise, remix and redistribute those free resources. Retaining allows instructors to maintain a copy of the resources (Hilton et al., 2013), and reusing means that instructors can directly use the whole or a portion of OER for their own purpose (Hilton,

2019), and revising and remixing grant instructors with permission to customize existing OER by making edits or merging with another open-licensed resource (Tang, 2021c). Then, redistribution makes it possible for instructors to disseminate those new or existing resources with students and even the academic community beyond the classroom (Tang et al., 2016; Hilton, 2016).

With the advantages of low costs and open licenses, OER provide a cost-effective alternative for instructors to meet individualized student needs to learn effectively. For example, Chiorescu (2017) reported a significant amount of savings ($13,681.95) in textbook spending for a total of 159 students enrolled in a college algebra course after open textbooks and other low-cost course materials were adopted. Meanwhile, OER initiatives and networks in higher education institutions and university systems have also boomed, such as Affordable Learning Georgia and the Maryland Open Source Textbook (MOST) initiative in the United States and the Teacher Education in Sub-Saharan Africa (TESSA) initiative in three African countries (Tang & Bao, 2020; 2021; 2022). Particularly, Affordable Learning Georgia, a statewide initiative in the state of Georgia, has served more than 535,000 students across 26 institutions and saved a total of $86.83 million since it launched in 2013 (Affordable Learning Georgia, n.d.).

More importantly, research has indicated that OER allow college students to maintain the same or even a higher level of learning effectiveness at a much lower cost. For example, Ross et al. (2018) reported that students' grades did not differ significantly between those who used open textbooks and those who used traditional textbooks in an introductory sociology course at a Canadian university. Ngimwa and Wilson (2012) also indicated that the TESSA initiative provided Sub-Saharan African pre-service teachers with affordable access to an effective learning experience. Further, Croteau (2017), synthesizing Affordable Learning Georgia program reports, found no significant difference in student learning outcomes such as Drop Fail Withdraw (DFW) rate, completion rate and course grade after open textbooks were adopted. Several additional studies found that student performance had a statistically significant improvement in those college-level courses that implemented open textbooks (Colvard et al., 2018; Jhangiani et al., 2018). Colvard et al., (2018) also added that OER may support educational equity, as Pell recipients in this study had a larger degree of growth in their grade point average and decline in their DFW rate than non-Pell recipients.

2.2 Teachers' value belief about technology

Teachers' value belief about technology refers to teachers' beliefs about the extent to which that integrating technology can accomplish professional and student needs (Ottenbriet-Leftwich et al., 2010; Vongkulluksn et al., 2018). Research has indicated that teachers' value belief about technology predicts their intention (Anderson & Maninger, 2007), knowledge (Hsu et al. 2017) and practice (Ertmer et al., 2012; Ottenbriet-Leftwich et al., 2010; Vongkulluksn et al., 2018) of technology integration in the classroom. Anderson and Maninger (2007) identified value belief as a critical factor of pre-service teachers' intentions to integrate technology in teaching. Besides, Hsu et al. (2017) reported that in-service teachers' technology knowledge and their

integration of digital games in the classroom were positively correlated to their value beliefs about teaching with digital games. Value beliefs also positively affected teachers' practice of technology integration in that American secondary teachers with a positive value belief about technology are more likely to work around first-order barriers such as accessing constraints and integrating technology in their classroom more than teachers who do not value technology (Vongkulluksn et al., 2018).

Teachers' value belief towards technology integration is a multi-dimensional variable as it involves considerations of multiple aspects of technology use in teaching practices (Ottenbriet-Leftwich et al., 2010; Vongkulluksn et al., 2018). Ottenbriet-Leftwich et al. (2010) classified college instructors' value belief of technology use into two categories: addressing professional needs and student needs. Addressing professional needs focuses on whether technology use can facilitate classroom operations, customize classroom materials and support personal professional development. For example, teachers use technology to customize course resources and tailor their instruction to course content (Ottenbriet-Leftwich et al., 2010). In addition, teachers apply technology to support their professional growth and their competence to deliver effective instructions (Kopcha, 2012; Ottenbriet-Leftwich et al., 2010). On the other hand, addressing student needs considers whether technology use can engage students, prompt students' higher order thinking skill,s and facilitate students' technology skills development. In particular, teachers' ultimate goal of integrating technology in the classroom is to benefit students by improving their motivation and engagement (Hsu et al. 2017; Ottenbriet-Leftwich et al., 2010).

2.3 College instructors' use of OER: beliefs, perception and practice

College instructors' value belief towards technology significantly predicts their perception and practice of integrating technology into their instruction (Ottenbriet-Leftwich et al., 2010; Vongkulluksn et al., 2018). Despite a lack of relevant evidence about college instructors' value belief about OER, research showed college instructors held positive beliefs about OER. For instance, Tlili et al. (2021) found college instructors surveyed in two Ghanaian universities held positive beliefs about OER. In a cross-nation study, Jung et al., (2017) found college instructors who had adopted open textbooks valued the merits of OER, worthy of the extra time spent on customizing the open content for their courses. In addition, most college instructors who used OER for teaching had positive perceptions of and experiences with OER. For example, Hilton et al. (2013) found a majority (83%) of mathematics instructors in a community college perceived OER used in their courses was of the same quality as or better than that of commercial textbooks. Jhangiani et al., (2016) found most surveyed instructors in a Canadian university considered the quality of OER equal or superior to that of textbooks and, in particular, instructors who had implemented OER recorded significantly higher ratings than those who had not. Jung et al., (2017) reported instructors from various countries indicated that OER had a comparable or higher quality than commercial textbooks. Ozdemir and Hendricks (2017) analyzed 51 faculty e-portfolios for the Cool4Ed (https://cool4ed.org) initiative and found faculties appraised the quality of OER were no worse than that of traditional textbooks.

However, the merits of OER have not yet convinced all the college instructors, especially given the barriers to integrating OER in their classrooms including cultural barriers, time constraints, and a lack of infrastructures (Mtebe & Raisamo, 2014; Tlili et al., 2021). For example, Mtebe and Raisamo (2014) indicated that some instructors doubted the authenticity and trustworthiness of OER being integrated into instruction. Additionally, Ngimwa and Wilson (2012) described African educators' concerns of sacrificing monetary benefits to use and produce OER, especially given they are usually not well-paid. On top of that, Tlili et al. (2021) reported Ghanaian instructors were skeptical about the potential risk of intellectual property involved in the use of OER and also worried about the challenges in search of appropriate OER for their teaching.

To overcome the barriers to using OER, providing college instructors with professional support is necessary (Tang, 2020). Understanding college instructors' value belief is critical to supporting their technology integration in teaching practices. Ottenbriet-Leftwich et al. (2010) indicate that professional support can be efficient only if instructors' value beliefs are addressed. To bolster OER adoption in higher education settings efficiently, understanding instructors' value beliefs about integrating OER in teaching is needed but nonexistent. Aligned with the work of Ottenbriet-Leftwich et al. (2010), this research thus investigated instructors' value beliefs towards using OER in college-level courses.

3 Methodology

3.1 Datasets

The dataset used was based on the OER user survey collected by the OER Research Hub to assess the impact of OER on teaching and learning (OERRH, 2014) in the Open University, UK. The dataset included survey responses from 1,819 educators including 675 K-12 teachers and 903 college instructors, 219 librarians and 5,460 learners (2,132 formal learners and 3,328 informal learners) from different countries (Farrow, de los Arcos, Pitt, & Weller, 2015). For different respondents, unique questions addressing the use of OER in their settings were provided. Specifically, the survey questions gauged the respondents' practices of using OER, beliefs about OER, perceived impact of OER and factors that may influence their choices of using OER (Farrow et al., 2015). Those survey questions were created by the OER Research Hub with the aim to investigate various hypotheses about open education, such as using OER can improve student performance and satisfaction about learning experiences, and the openness of OER leads to a unique experience of adopting and using OER in various settings. The survey responses were all de-identified in order to follow the ethical requirement and protect respondents' privacy.

3.2 Participants

Given our focus on college instructors, we thus selected participants based on two criteria. First, this research only included instructors teaching at a higher education

institution. We first determined whether respondents met this criterion based on their responses to the questions, "What is your role?" and "Within which educational context(s) do you work?" A total of 566 respondents were identified as college instructors. Second, only college instructors who specified their value belief about using OER were retained. Similarly, the filtering process was based on college instructors' responses to the question "For which of the following purposes have you used OER?". We removed 53 college instructors who did not respond to those items which led to a sample of 513 participants for the study.

Among the 513 participants, 217 were female, 288 were male, 3 were transgender and 5 participants' gender information was missing. Participants came from 83 countries, 487 of whom recorded their first language and 307 were native English speakers. A total of 328 marked their teaching experience, and over half of them ($n=193$) had taught for at least ten years in higher education settings.

3.3 Variables

3.3.1 College instructors' value belief about using OER

To investigate college instructors' value beliefs towards using OER, we focused on survey responses to the question, "For which of the following purposes have you used OER?" Specifically, this question consisted of 17 statements and one open-ended Item marked as "other" with room for text explanations if needed. Teachers responded to each of these statements, marking either "Yes" (1) or "No" (0) to indicate whether that statement aligned with their value belief. Specifically, the items were aligned with value belief framework proposed by Ottenbriet-Leftwich et al. (2010) with a focus on addressing professional needs and student needs (see Fig. 1). For professional needs, five items were related to instructors' beliefs towards OER's value for customizing classroom materials and seven items were mapped to promoting professional development for instructors. For student needs, five items were specifically linked to engaging students. For this study, we examined the three subscales subsuming instructors' value belief about technology.

To validate the survey items, we examined the validity and the reliability of the survey items. For the validity, the survey items were reviewed and approved by three educational researchers with expertise in OER, technology integration, and educational measurement. For the reliability, Cronbach's α coefficient was calculated for the survey items about value belief. The value ($\alpha = 0.907$) indicated that the survey for this study is highly reliable. We further computed Cronbach's alpha coefficient for the three subscales of value beliefs, with customizing classroom materials at 0.768, supporting professional development at 0.828 and engaging students at 0.783, indicating the reliability levels for the subscales were either acceptable or high.

3.3.2 Distal outcomes

To evaluate how instructors' value beliefs influenced their practice and perception of using OER, we also investigated the effect of college instructors' value beliefs and the corresponding levels on two distal outcome variables.

The first distal outcome variable was whether instructors adapted OER in their practice of using OER, rather than simply retained or reused existing OER. This variable was gauged by the instructors' responses to the item "I have adapted OER to fit my needs". This item is a dichotomous question with response options "Yes" (1) and "No" (0). A total of 289 college instructors responded to this item, with 220 of whom answered "Yes" and 69 answered "No".

The second distal outcome variable was instructors' perceptions of whether OER helped them satisfy student needs when they used OER. This variable was evaluated by the instructors' responses to the item "Allows me to better accommodate diverse learners' needs". This item is a 5-point Likert-type item with options of responses ranging from "Strongly disagree" (1) to "Strongly agree" (5). Among the 259 instructors who responded to this item, 11 selected "Strongly disagree", 4 selected "Disagree", 95 selected "Neither Agree or Disagree", 104 selected "Agree" and 45 selected "Strongly Agree".

3.4 Diagnostic classification model

Diagnostic classification models (DCMs; Rupp et al., 2010; von Davier & Lee, 2019) are a class of multidimensional latent class models that can provide feedback about participants' levels of a latent trait. These latent traits are usually referred to as *attributes*. Most DCMs focus on classifying participants into dichotomous attribute mastery levels, that is, non-presence or presence. In some cases, researchers or stakeholders may seek additional feedback about more than two levels of latent traits. This type of research question can be answered by applying a polytomous-attribute DCM (Bao, 2019; Bao & Bradshaw, 2018; Templin & Bradshaw, 2014).
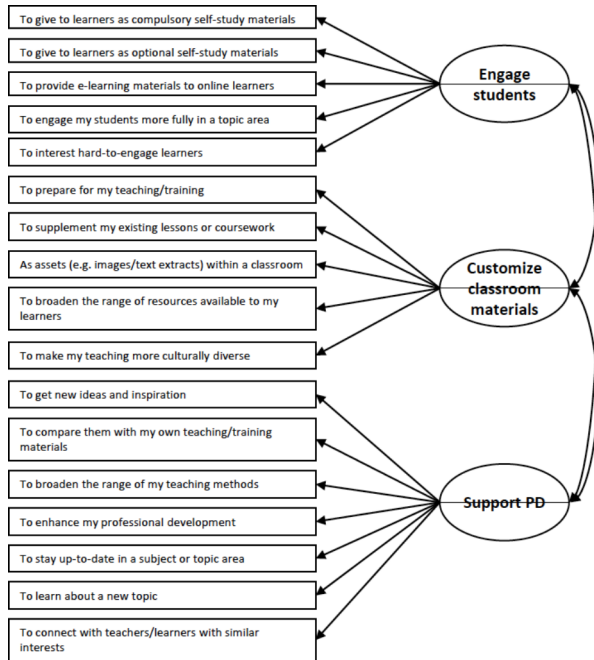
We assume a survey instrument, or a test contains I items and measures A attributes. Each Item measures one or more attributes. In this paper, we use a vector $\boldsymbol{q_i} = (q_{i1}, \cdots, q_{iA})\prime$ to indicate which attributes are measured by Item i, where the element of the vector $q_{ia}=1$ represents Item i and measures Attribute a and $q_{ia} = 0$ represents Item i does not measure Attribute a. The item response for Examinee e who has an attribute profile $\boldsymbol{\alpha_e}$ is denoted as X_{ei}. For a polytomous-attribute DCM (PDCM) that measures three attribute mastery levels, we label the three levels of a polytomous attribute as *low*, *medium* and *high*. For an item measuring Attribute a with l_a levels, we define $(l_a - 1)$ dummy-coded dichotomous variables $\alpha_{ea}^1, \alpha_{ea}^2, \cdots, \alpha_{ea}^{(l_a-1)}$ to represent the attribute levels for Examinee e.

The general form of the PDCM that models the probability of endorsing an item when Examinee e with attribute profile $\boldsymbol{\alpha_e}$ responds to Item i is

$$\log\frac{P(X_{ei} = 1|\boldsymbol{\alpha}_e)}{P(X_{ei} = 0|\boldsymbol{\alpha}_e)} = \lambda_{i,0} + \sum_{a=1}^{A}\sum_{l=1}^{l_a-1}\lambda_{i,1,(a)}^l\alpha_{ea}^l q_{ia} + \sum_{a=1}^{A-1}\sum_{l=1}^{l_a-1}\sum_{a'=a+1}^{A}\sum_{l'=1}^{l_{a'}-1}\lambda_{i,2,(a,a')}^{ll'}\alpha_{ea}^l\alpha_{ea'}^{l'} q_{ia}q_{ia'} + \cdots$$

where α_{ea}^l is the dummy variable for level l of attribute a and q_{ia} is a 0/1 indicator of whether Item i measures attribute a, where 1 indicates that Item i measures attribute a and 0 indicates the opposite. $\lambda_{i,1,(a)}^l$ is the main effect for level l of attribute a and $\lambda_{i,2,(a,a')}^{ll'}$ is the two-way interaction for level l of attribute a and level l' of attribute $a\prime$. The ellipsis represents the summation of the possible three-way or higher-order

Fig. 1 Path Diagram for College Instructors' Value Beliefs

| To give to learners as compulsory self-study materials |
| To give to learners as optional self-study materials |
| To provide e-learning materials to online learners |
| To engage my students more fully in a topic area |
| To interest hard-to-engage learners |
| To prepare for my teaching/training |
| To supplement my existing lessons or coursework |
| As assets (e.g. images/text extracts) within a classroom |
| To broaden the range of resources available to my learners |
| To make my teaching more culturally diverse |
| To get new ideas and inspiration |
| To compare them with my own teaching/training materials |
| To broaden the range of my teaching methods |
| To enhance my professional development |
| To stay up-to-date in a subject or topic area |
| To learn about a new topic |
| To connect with teachers/learners with similar interests |

Engage students

Customize classroom materials

Support PD

interactions that would be present if the Item measured three or more attributes. The main effects or interaction terms are present in the item response function only when examinee *e* has reached the corresponding level(s) *and* the attribute(s) are measured by Item *i*.

Figure 1 further clarifies the alignment between the survey items with the latent attribute structures under the DCM framework. The squares represent the 17 items measuring college instructors' value beliefs in the survey. Note that the responses were dichotomous for all the items. The three circles represent the three latent constructs regarding instructors' value beliefs towards using OER, including engaging students, customizing resources and supporting professional development. The bar in the middle of each circle indicates that the latent variable is categorical. The arrows from the latent variables to the items depict the mapping between an item and an attribute. For example, the arrow between the latent variable "Engage students" and "To give to learners as compulsory self-study materials" means the Item measures how likely a college instructor was to use OER as required self-learning materials to engage students in an online course. Moreover, DCMs also estimate the correlations among the latent attributes as the structural equation models although the attributes are categorical, represented by the double arrows between any two latent attributes. Incorporating such attribute structure can further reduce the model estimation errors (Rupp et al., 2010).

In this study, we investigated the three DCMs, the general PDCM as introduced above, the constrained PDCM (cPDCM) in which we fixed the main effects for different attribute levels to be equal, and the dichotomous-attribute version of the PDCM, which is equivalent to the loglinear cognitive diagnostic model (LCDM; Henson,

Templin, & Rupp, 2009). The application of the cPDCM in the data analysis aims to reduce the number of item parameters to be estimated so that a more parsimonious model can be fitted to the item responses and thus improve the potential model fit. The constraints indicate that the increase of the probability of endorsing an item is pre-assumed to be equal across different attribute levels. The LCDM, on the other hand, can also be considered as the constrained model of the PDCM where there are only two attribute categories instead of two or more categories.

3.5 Model evaluation

To identify the best fitting model used in this study, we computed the information-based indices including Akaike Information Criterion (AIC; Akaike, 1974), Bayesian Information Criterion (BIC; Schwarz, 1978), sample-adjusted BIC (SABIC; Sclove, 1987) and Bozdogan's consistent AIC (CAIC; Bozdogan, 1987). Note that a small value of an index indicates a better fit of the model to the observed responses.

3.6 Analysis for distal outcome variables

Since the latent attributes and the distal outcome variables were all categorical, we further conducted logistic regression for the item "I have adapted OER to fit my needs", and the analysis of variance (ANOVA) for the item "Allows me to better accommodate diverse learners' needs". The independent variables for both analyses included the levels of college instructors' value beliefs obtained from the DCM classification results. We then investigated the significance for each value belief to make inferences about the effect on the two distal outcome variables.

4 Result

4.1 RQ1: what are college instructors' value beliefs about integrating OER in teaching?

4.1.1 Model fit

Among the three models investigated in this study (see Table 1), the cPDCM consistently had smaller values for all the model fit indices. This indicates that it is reasonable to assume the main effects for different attribute levels are the same and thus the cPDCM can be used as the best fitting model for the follow-up analysis. Moreover, the LCDM did not yield a comparable fit as the PDCM and the cPDCM, which indi-

		AIC	BIC	SABIC	CAIC	Log likelihood
Table 1 *Model Fit Statistics for Different Diagnostic Classification Models*	PDCM	8642.515	8969.016	8724.606	8774.195	-4244.258
	cPDCM	8625.760	8880.176	8689.727	8728.367	-4252.880
	LCDM	8889.720	9063.570	8862.315	9104.570	-4403.860

Fig. 2 Summary of participants' value belief
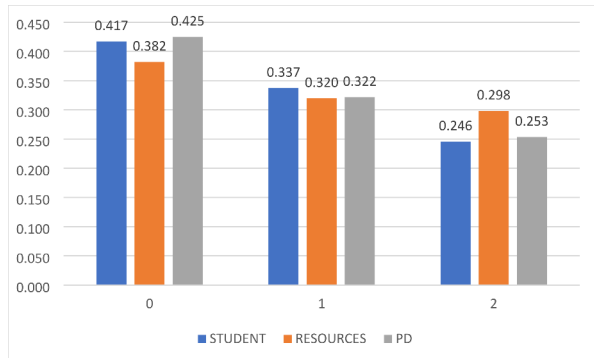
cates that the college instructors' value beliefs can be classified into three levels for each latent variable.

4.1.2 Classification of participants' value belief

One advantage of using the DCM framework is that the models can classify participants into a group of pre-determined latent classes. In our study, we employed three subscales of value beliefs in line with Ottenbriet-Leftwich et al.'s (2010) framework, since we specified three proficiency levels for each value belief for the PDCM model. Accordingly, the model classifies each participant into one of the twenty-seven profiles indicating a participant's combination of proficiency levels across value beliefs. Figure 2 demonstrates the overall classification for all participants for each value belief under the cPDCM. Each proficiency group contains large proportions of participants ranging from 24.6 to 42.5%. Among the three proficiency levels, most participants were classified into the lowest proficiency level with the proportion ranging from 38.2 to 42.5%. For all three value beliefs, about one third of participants were classified into the medium proficiency level. The highest proficiency level contains the fewest participants for all three value belief groups ranging from 24.6 to 29.8%. This shows that people who are using OER might lack a higher level of value belief and increasing the value belief of teachers in higher education institutions could prompt the efficiency of the utilization of OER.

4.1.3 Item parameter estimate

Table 2 shows the item parameters estimates for the 17 items we investigated in this study. The first column represents the item numbers that correspond to the item order mentioned previously. Columns 2 to 5 represent the item parameter estimates where Column 2 includes the item parameter estimates for intercepts and Columns 3 to 5 include the item parameter estimates for main effects. Since each item only measures one attribute (e.g., a subscale of college instructors' value beliefs about OER), we only presented the main effect estimate for the measured attribute and left the remaining cells blank, meaning these attributes were not measured by the item. Furthermore, we computed the probability of selecting "Yes" for each item when an examinee belongs to the low, medium or high group. The last column illustrates the

Table 2 Item Parameter Estimates for the Constrained-PDCM

Item	Intercept	Student	Resources	Professional Development	IRP for Low-level Group	IRP for Medium-level Group	IRP for High-level Group	Item Discrimination
1	-0.641(0.213)		1.586(0.196)		0.345	0.720	0.926	0.581
2	-0.184(0.178)			2.714(0.350)	0.454	0.926	0.995	0.541
3	-1.244(0.353)		2.462(0.252)		0.224	0.772	0.975	0.752
4	-3.003(0.500)		2.597(0.320)		0.047	0.400	0.899	0.852
5	-3.205(0.391)	1.859(0.234)			0.039	0.207	0.626	0.587
6	-2.421(0.456)	2.661(0.356)			0.082	0.560	0.948	0.866
7	-3.102(0.403)	2.334(0.288)			0.043	0.317	0.827	0.784
8	-2.776(0.270)			2.147(0.228)	0.059	0.348	0.820	0.762
9	-2.333(0.411)			3.035(0.337)	0.088	0.669	0.977	0.888
10	-2.344(0.459)		2.752(0.306)		0.088	0.601	0.959	0.872
11	-3.336(0.454)		1.994(0.221)		0.034	0.207	0.657	0.623
12	-1.677(0.264)			2.284(0.230)	0.157	0.647	0.947	0.790
13	-2.001(0.303)			2.732(0.279)	0.119	0.675	0.970	0.851
14	-1.471(0.270)			2.489(0.253)	0.187	0.735	0.971	0.784
15	-2.875(0.489)	2.854(0.353)			0.053	0.495	0.944	0.891
16	-3.620(0.346)			2.436(0.284)	0.026	0.234	0.778	0.752
17	-3.889(0.526)	2.623(0.310)			0.020	0.220	0.795	0.775

item discrimination values by computing the differences between the item response probability of selecting "Yes" for an item when examinees are from the high group and when examinees are from the low group.

Note that among the 17 items, 5 items measured instructors' value belief of engaging students, 5 items measured the value belief of customizing classroom materials and 7 items measured the value belief of supporting professional development. The intercept estimates ranged from -3.889 to -0.184, where the corresponding item response probability ranged from 0.020 to 0.454. The main effects for the three types of value beliefs are all significantly higher than 0, ranging from 1.586 to 3.035 with the standard errors smaller than 0.353, inferring a strong increase of the probability for selecting "Yes" for the given item. The estimates of the main effects show that each item contributes enormously to the classification of the possession of one attribute.

In addition, the presentation of the probabilities of selecting "Yes" for each item by college instructors in different groups of value beliefs in Columns 6 to 8 provides additional support for examining the instructors' response behaviors and the item quality. The item response probability for the low-level group ranges from 0.020 to 0.454, representing how likely a teacher would select "Yes" for the item, where a smaller value indicates less probability. Similarly, the item response probability ranges from 0.207 to 0.926 for the medium-level group. This shows how likely a teacher from the medium level group is to select "Yes" for an item. For example, for Item 1, the probability of selecting "Yes" increased from 0.345 to 0.720 when we compared two teachers from the low-level and the medium-level group, respectively. Again,

Note. The numbers in the parentheses are the standard errors of the estimates. IRP represents item response probability which is the probability of selecting "YES" for an item. Item discrimination=IRP for the high-level group – IRT for the low-level group.

Column 8 presents the item response probability for the teachers from the high-level group, ranging from 0.626 to 0.995. Column 9 illustrates the item discrimination which equals the highest item response probability and the lowest item response probability ranging from 0.541 to 0.891. This indicates that the items in general can separate teachers from the low and high groups.

Figure 3 shows the item response probability for Items 1 and 9 across the three groups. As presented in Table 2, the intercept for Item 1 is higher than that for Item 9, resulting in a lower item response probability for Item 1 for the low-level group. Similarly, the main effect for Item 1 is smaller than that for Item 9, which leads to the larger increase of the item response probability for the medium-level group and the high-level group. Therefore, Item 9 has overall higher item discrimination than Item 1.

4.2 RQ2. What is the influence of instructors' value belief on their practices of using OER in teaching?

Table 3 summarizes the logistic regression results for the item "I have adapted OER to fit my needs". The item provided two options, "Yes" and "No," for teachers who

Fig. 3 Example Item Response Theory for Item 1 and Item 9

	Low	Medium	High
Item 1	0.345	0.720	0.926
Item 9	0.088	0.669	0.977
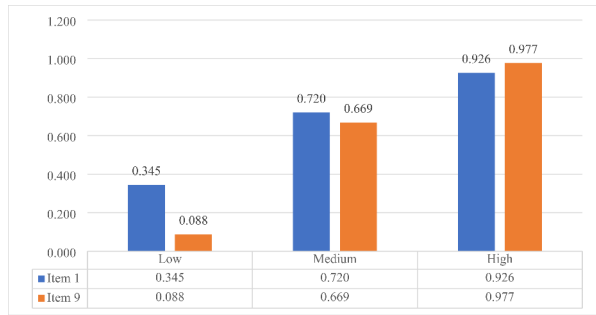
Table 3 Logistic Regression for Item "I have adapted OER to fit my needs"

	Estimate	Std. Error	z	p
(Intercept)	0.159	0.257	0.617	0.537
Student-level1	-0.334	0.721	-0.463	0.644
Student-level2	0.358	0.930	0.385	0.700
Resources-level1	0.703	0.758	0.927	0.354
Resources-level2	-0.226	1.070	-0.211	0.833
PD-level1	1.061	0.413	2.570	0.010*
PD-level2	1.933	0.738	2.618	0.009*

Table 4 Analysis of Variance for the First Covariate

	Degree of Freedom	Sum of Square	Mean Square	F	p
Student	1	17.247	17.237	21.446	<0.001
Resources	1	0.341	0.341	0.424	0.515
PD	1	0.493	0.493	0.613	0.434
Residual	255	204.96	0.804		

participated in this survey. The independent variables are college instructors' levels for value beliefs of using OER to engage students, customize classroom materials and support personal professional development which were treated as categorical. Results in Table 3 show that engaging in professional development is significant for both levels to endorse this item ($z=2.570$, $p=.010$, and $z=2.681$, $p=.009$), with esti-mated coefficients equal to 1.061 and 1.933. This result shows that an increase in the level of value belief about using OER to support personal professional development has a positive effect on the likelihood of adapting OER in the use of OER rather than simply reusing existing OER.

Table 4 shows the ANOVA analysis for endorsing a five-point Likert-type item "Allows me to better accommodate diverse learners' needs". Instructors who have high level value beliefs of using OER to engage students yielded a significant result ($F(1,255)=21.446$, $p<.001$) in endorsing this item, while the other two value belief variables, using OER to customize resources and support personal professional development, yielded non-significant results. Furthermore, Fig. 4 demonstrated the more detailed proportions for different level groups for instructors' value belief of using OER to engage students, where the columns represent the five Likert-type scale

Fig. 4 The Proportion of Participants for Different Levels of Value Belief of Engaging in Student and Items Response for "Allows me to better accommodate diverse learners' needs"
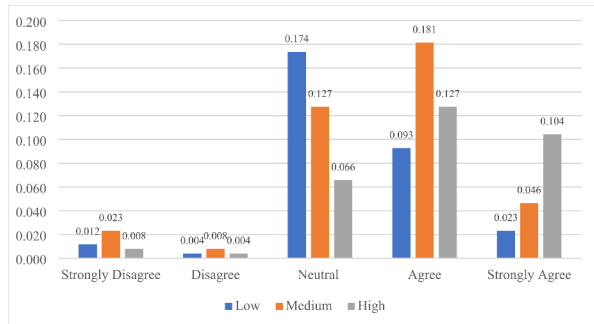
and the rows represent the three different groups. This table shows a clear trend of an increase in selecting "Agree" instead of "Disagree" across the three levels. Especially, the proportion of selecting "Strongly Agree" increased from 2.3 to 10.4% when the value belief increased from a low to a high level. On the other hand, the options "Agree" and "Neutral" contained the largest proportion of instructors' responses, 18.1% and 17.4% respectively, for the medium-level group and the low-level group.

5 Discussion

Understanding college instructors' value beliefs towards using OER is important for reinforcing the adoption of OER in college-level courses and thereby further reducing educational costs to attend higher education, but such an understanding is absent. This exploratory study initiated the inquiry of what college instructors' value beliefs were towards using OER, whether any differences existed in college instructors' value beliefs, and how the difference, if any, predicted college instructors' usage of OER in their teaching practices.

5.1 RQ1: what are college instructors' value beliefs about integrating OER in teaching?

This study revealed college instructors' value beliefs towards using OER in teaching practices as a multidimensional variable (Ottenbriet-Leftwich et al., 2010; Vongkulluksn et al., 2018). The item and person analysis results of DCM confirmed the three dimensions of value beliefs based on Ottenbriet-Leftwich et al.'s (2010) categories of teachers' value beliefs towards technology integration, including engaging students, customizing resources, and professional development. This finding provided a preliminary understanding of what college instructors valued when implementing OER in their teaching practices (Jung et al., 2017; Tlili et al., 2021).

Beyond a descriptive account of instructors' value beliefs about OER, the DCM analysis also gauged the difference in college instructors' value beliefs using a polytomous-attribute DCM (Bao, 2019; Bao & Bradshaw, 2018; Templin & Bradshaw, 2014). The DCM findings revealed three different levels of value beliefs (e.g., low, medium, and high), which made it possible to look for nuances of college instructors' value beliefs about OER and explore how pre-determined latent classes of value

beliefs impacted their implementation of OER in teaching practices (Vongkulluksn et al., 2018). Around 40% of college instructors in the study had a relatively low level of value beliefs in each of the three dimensions. In contrast, only less than 30% of college instructors reported a high level of value beliefs in each dimension. Given that value belief is a predictor of teachers' intention of technology integration (Anderson & Maninger, 2007; Hsu et al. 2017), providing effective interventions to foster college instructors' strong value belief towards using OER is necessary. Our speculation is that those with a low level of value belief about using OER probably still had a low awareness of the inherent advantages of using OER. On the other hand, those teachers with low or medium level of value beliefs may also just get involved in the adoption of OER indifferently rather than actively seeking effective ways to integrate OER to support individualized instruction. Many higher education institutions and university systems have established OER initiatives and networks and have provided various opportunities and rewards encouraging instructors to implement OER in their classes (Read et al., 2020; Rets & Rogaten, 2021). To maximize the positive momentum that those initiatives can potentially result in, affording instructors with a comprehensive and engaging experience with OER is critical (Wiley, 2021). Open educational practices may provide instructors with a contextualized experience of implementing OER in college-level courses via a series of activities such as searching, adapting, customizing, and redistributing OER (Tlili et al., 2021; Van Allen & Katz, 2019). Additionally, professional development with a focus on raising instructors' awareness of OER may help boost the perception of the benefits of OER for instructors with a lower level of value beliefs about OER (Chiorescu, 2017; Hilton, 2019).

5.2 RQ2. What is the influence of Instructors' value belief on their practices of using OER in teaching?

The findings of this study indicated that instructors with higher perceived values towards using OER for professional growth recorded a higher likelihood of adapting OER in their teaching practices rather than merely reusing existing resources. Teachers who used technology for professional development may expect a more individualized and accessible program for their professional growth (Ottenbriet-Leftwich et al., 2010). Actually, OER can address instructors' needs by affording a more flexible option to access professional resources that are more tailored to their own needs at any time without any cost (Tlili et al., 2021; Hendricks et al., 2017). This may account for why this class of instructors recorded a higher likelihood of adapting OER for personal needs, but on the other hand it raises the concern regarding whether college instructors adapted OER or just reused OER, especially given that an increase in instructors' perceived value about using OER to engage students and customize course resources does not strengthen their tendency to adapt OER. This result reinforced the need to include the adaptation of OER in college instructors' professional development program. In contrast, instructors with higher perceived values of OER in engaging students were more positive about the potential of OER in affording differentiated instruction and accommodating students' individualized needs. This result also echoes the findings from prior studies that OER can decrease students' educational costs for attending a college-level class, but student engagement can keep the

same level as or even become higher than that in the same course adopting traditional textbooks (e.g., Colvard et al., 2018; Jhangiani et al., 2018). This result is not surprising but promising, though further evidence on how student engagement was fostered is needed.

From the perspective of methodological implications, the DCM item analysis results suggested that each item contributed enormously to the classification of college instructors' possession levels of value beliefs. Through the model comparison process, we selected the most parsimonious model, the constrained-PDCM, to conduct the follow-up analysis. The main effects for all items in the constrained-PDCM, representing the amount of probability college instructors would gain to endorse an item, were significantly larger than 0. The positive values of the item parameter estimates revealed that college instructors who were at a higher level of a certain value belief could be efficiently differentiated from those with a lower level of that specific value belief. This finding can also be supported by the large item discrimination values. The significant item parameter estimates also verified the construct validity of the survey that each item plays a prominent role in measuring the three dimensions aligned with Ottenbriet-Leftwich et al.'s (2010) framework.

5.3 Practical implications

The findings provided significant implications of offering professional development opportunities relevant to college instructors' needs to use OER in their teaching practices. First, faculty professional development teams may embed OEP in the training programs to model the practice of effectively using OER (e.g., adaptation). College instructors who tend to use OER to engage students and customize course resources may need more elaborated training on adapting OER. Second, faculty professional development teams may consider increasing college instructors' awareness of OER, especially the advantage of OER in affording cost-effective, customized courses. A majority of college instructors still did not have a high level of value beliefs towards integrating OER in each of the dimensions. Third, OER initiatives in higher education settings should consider supporting college instructors' value beliefs about using OER in their teaching practices rather than just focusing on the difference in textbook costs and student achievement during and after their adoption of OER.

5.4 Limitations and future research

The findings of this study were limited by several constraints. First, the items relevant to value beliefs did not originate from a validated instrument but were based on the definitions in prior works (Ottenbriet-Leftwich et al., 2010). Subjective interpretations may decrease the validity of the coding procedures and the findings of this study. Second, this study only collected self-reported data about college instructors' perceptions of their value beliefs to use OER. Future research may consider including multiple sources of data to investigate college instructors' value beliefs and their impact on teaching and learning practices. Also, developing and validating an instrument that specifically assesses college instructors' value beliefs about using OER in teaching practices can also be the direction of future research.

Declarations

Competing Interests The authors declare that they have no competing interests.

Conflict of interest None.

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