

How Universal Design for Learning (UDL) is related to Differentiated Instruction (DI): The mediation role of growth mindset and teachers' practices factors

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**How Universal Design for Learning (UDL) is Related to Differentiated Instruction (DI):
The Mediation Role of Growth Mindset and Teachers' Practices Factors**

Abstract

Inclusive education, crucial for human rights and sustainable development, focuses on integrating and empowering students of varying needs and abilities. Understanding the interaction between Universal Design for Learning (UDL) and Differentiated Instruction (DI) is key for educators and stakeholders to implement inclusive strategies effectively. Yet, there is a significant gap in empirical research exploring this relationship. Therefore, this study examined a proposed model combining growth mindset and practice factors (ongoing assessment and flexible grouping), which explained how UDL is related to DI. Structural equation modeling was used to analyze data from 647 in-service teachers. The findings showed that practice factors independently and in combination with a growth mindset fully mediated the relationship between UDL and DI. The implications for the research community, teachers, and teacher educators to implement UDL and DI are presented.

Keywords: Universal Design for Learning; Differentiated Instruction; Inclusive Education; Flexible Grouping; Ongoing Assessment; Growth Mindset

1. Introduction

Implementing inclusive education is pivotal for advancing human rights and sustainable development, ensuring the integration and empowerment of students with diverse learning needs, including those with disabilities (the United Nations Educational, Scientific and Cultural Organization (UNESCO), 2023).

Universal Design for Learning (UDL) and Differentiated Instruction (DI), two important pedagogical approaches to achieving inclusive education, are effective strategies for meeting students' diverse needs (Hall et al., 2003). They focus on variability in learning, accommodating students' different learning interests and styles (van Munster et al., 2019). UDL and DI are both a philosophy and practice of teaching focusing on the variability in learning (Patrick et al., 2007; Tomlinson, 2014). Successful implementation of UDL and DI hinges significantly on three key elements: the growth mindset of teachers, the practice of ongoing assessment, and the application of flexible grouping strategies in the classroom (Griful-Freixenet et al., 2020).

Dweck (2006) defines a growth mindset as a belief spectrum about intellectual malleability, contrasting with a fixed mindset. Teachers embracing a growth mindset view student ability as developable through effort and education, fostering a collaborative classroom atmosphere (Leroy et al., 2007). Conversely, those with a fixed mindset perceive student abilities as unchangeable, often leading to more authoritarian teaching styles and competitive classroom environments (Leroy et al., 2007; Trouilloud et al., 2006).

Ongoing assessment uses student performance data regularly to adjust and improve the curriculum. This method is useful for both teaching and learning, playing a key role in improving education for all students and fostering environments that support inclusive education (Bi et al., 2023; Coubergs et al., 2017).

Flexible grouping is a dynamic classroom strategy involving the formation of both similar and diverse student groups (Tomlinson et al., 2003). Teachers apply flexible grouping to align students with appropriate tasks, facilitating observation and assessment under various conditions. This method is noted for enhancing inclusive education practices (Coubergs et al., 2017).

Research has been delving into the connection between UDL and DI, revealing overlaps and various interrelationships, including complementary, embedded, and incompatible aspects (Griful-Freixenet et al., 2020). This area of study, while gaining traction, still has

three unexplored research needs, which this work aims to address, expanding the understanding of UDL and DI in educational practices.

First, Griful-Freixenet et al. (2020) have theoretically explored various interrelationships between UDL and DI. This study marks a progression from theoretical analysis to empirical investigation, aiming to establish an evidence-based understanding of the UDL and DI relationship. Such empirical research represents a significant advancement in developing robust theories in inclusive education research. Thus, the first objective is to examine the interplay between UDL and DI empirically.

Second, previous research on the relationship between UDL and DI has primarily focused on pre-service teachers, who have less experience than in-service teachers. This limitation highlights the need for research involving in-service teachers, who can provide more nuanced insights based on their classroom experience (van Munster et al., 2019; Wen & Cai, 2024). Therefore, the second objective of this study is to explore the dynamics of UDL and DI among in-service teachers.

Third, while prior research has significantly contributed to understanding the relationship between UDL and DI, the specific mechanisms through which UDL influences DI have not been thoroughly examined. Identifying these mediating mechanisms is crucial for advancing knowledge of UDL and DI and providing guidance for teacher interventions aimed at promoting inclusive education. Thus, the third objective is to confirm the mediating mechanisms of growth mindset, ongoing assessment, and flexible grouping in the relationship between UDL and DI.

Against this backdrop, this study utilized a sample of Chinese in-service teachers to address the following main research questions:

1. how is universal design for learning related to differentiated instruction?
2. to what extent do growth mindset, ongoing assessment, and flexible grouping mediate the relationship between UDL and DI, individually and collectively?

2. Theoretical Framework and Hypotheses Development

This section first explains the meaning of UDL and DI. It then examines the direct effects of UDL and DI. It also investigates the linkages and indirect influences among UDL, DI, teacher philosophy, and practice factors. We made the hypothesized model based on the literature review (see Fig.1).

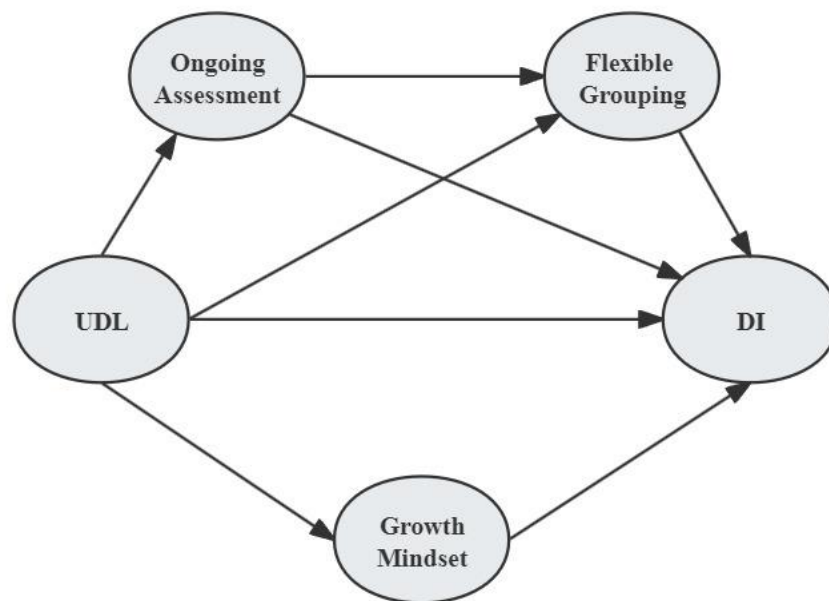


Figure 1 The Hypothesized Model

Note. UDL=Universal Design for Learning; DI=Differentiated Instruction

2.1 The Definition of UDL and DI

UDL model comes from the architectural paradigm of Universal design (UD) and it contains three underlying principles: 1) multiple means of representation (concentrating on how students gather, and organize facts through what they see, hear, and read, and presenting information in a variety of ways), 2) expression (encouraging students to express what they know besides traditional spoken and written methods), and 3) engagement (keeping students interested in learning) (Rose & Meyer, 2002; Selmer & Floyd, 2012).

DI is a teacher's proactive response to students' needs shaped by teachers' philosophy or beliefs (Tomlinson, 2014). Teachers can provide DI through content, process, product, and affect or environment based on students' readiness (a student's current proximity to specified learning goals), interests (passions that motivate learning), and learning profile (preferred approaches to take in, explore, or express content) (Tomlinson & Imbeau, 2010).

Concretely, content refers to the knowledge, comprehension, and competencies they want students to learn to reach their learning goals. Process means how students understand, absorb, and make sense of the content. The product explains how students demonstrate what they know, understand, and can do. Affect or environment indicates how students' emotions and feelings influence their motivation to learn and ability to cooperate with their peers (Tomlinson, 2014).

2.2 The Relationship between UDL and DI

There are three types of interrelationships between Universal Design for Learning (UDL) and Differentiated Instruction (DI): complementary, embedded, and incompatible (Griful-Freixenet et al., 2020). This article primarily focuses on complementary and embedded relationships (see Table 1).

Numerous studies suggest that UDL and DI complement each other (e.g., Beasley & Beck, 2017; Cha & Ahn, 2014; Griful-Freixenet et al., 2017; Lee & Picanco, 2013). Beasley and Beck (2017) suggested that UDL and DI complement each other well, as both aim to meet students' needs by tailoring the curriculum and implementing multiple diverse methods. Similarly, Griful-Freixenet et al. (2017) noted that UDL and DI share the understanding that each learner is unique, requiring educators to select appropriate assessments and curricula accordingly. Cha and Ahn (2014) emphasized that applying DI by providing assessment options based on student strengths and weaknesses can enhance the success of UDL implementation. They emphasized the importance of ongoing assessments of students' knowledge and skills and authentic tasks to monitor learning and provide continuous feedback. Lee and Picanco (2013) identified one element of DI as the diversity of learning achievable through the three UDL principles: multiple means of representation, action and expression, and engagement. Specifically, the first principle involves presenting learning content in various methods tailored to the learning stage and students' unique characteristics. The second principle allows learners to express their learning ideas most comfortably, including diversified assessment methods like verbal, written, and performance assessments. The third principle ensures multiple ways of keeping students engaged in learning, using various tasks adapted to the learning phases to maintain interest based on teachers' observations.

Several studies support the idea that DI is embedded within the UDL framework (e.g., Katz & Sugden, 2013; Selmer & Floyd, 2012; Tobin, 2008). Tobin (2008) emphasized that an

effective, differentiated literacy course must focus on universal design, allowing teachers to tailor individual instruction for student success. Katz and Sugden (2013) included DI within the Three three-block model (TBM) of UDL, specifically in instructional practice (block 2). In this block, students choose how to develop theoretical understanding, engage in activities, and select materials, prompting teachers to differentiate learning opportunities to meet diverse needs. Selmer and Floyd (2012) found that a curriculum with a UDL framework inherently compels teachers to differentiate instruction to reduce student access to mathematics barriers.

Given the substantial evidence of a correlation between UDL and DI, we propose the following hypothesis:

Hypothesis 1. UDL is positively related to DI

Table 1 The interrelationships between UDL and DI

Interrelationship	Description	Supporting Studies	Key Principles/Practices
Complementary	UDL and DI complement each other by tailoring the curriculum and implementing diverse methods to meet students' needs.	Beasley & Beck (2017), Cha & Ahn (2014), Griful-Freixenet et al. (2017), Lee & Picanco (2013)	Tailoring Curriculum: UDL and DI both aim to meet students' needs by tailoring the curriculum (Beasley & Beck, 2017). Diverse Methods: Both frameworks implement multiple diverse methods (Griful-Freixenet et al., 2017). Ongoing Assessments: DI involves providing assessment options based on student strengths and weaknesses, enhancing UDL (Cha & Ahn, 2014). DI's diversity is realized through UDL's principles (Lee & Picanco, 2013)
Embedded	DI is seen as a component within the UDL framework, prompting teachers to differentiate instruction to meet diverse needs.	Katz & Sugden (2013), Selmer & Floyd (2012), Tobin (2008)	Three-Block Model (TBM) of UDL: DI is included in instructional practices (block 2), where students choose how to engage in activities (Katz & Sugden, 2013). Differentiated Literacy Course: Focus on universal design to tailor individual instruction (Tobin, 2008). Reducing Barriers: A UDL curriculum compels teachers to differentiate instruction in mathematics to reduce barriers (Selmer & Floyd, 2012).

2.3 The Mediation Role of Growth Mindset

Tomlinson and Imbeau (2010), along with Hattie (2012), have identified that the beliefs and mindsets of teachers play a crucial role in influencing both student learning and teaching methods. Stemming from Dweck's (2006) theory, two distinct mindset types are identified: fixed and growth. Teachers harboring a fixed mindset tend to believe in the innate nature of students' intelligence and abilities, while those with a growth mindset perceive these attributes as flexible and improvable through effort and education. Tomlinson (2014) suggests that teachers with a growth mindset are more inclined towards implementing differentiation, actively seeking ways to foster development in students with varied interests, readiness levels, and learning profiles. Research by Coubergs et al. (2017) and Gheysens et al. (2020) further confirms that a growth mindset is a significant predictor of differentiated instruction. This mindset not only increases the likelihood of employing differentiated instruction but also influences the extent to which teachers engage with students' individual needs. Moreover, Griful-Freixenet et al. (2020) found that a growth mindset critically affects the relationship between recognizing inclusive classroom contexts and applying differentiated teaching practices. In a similar vein, Hattie (2012) discovered a strong connection between teachers' intentions to implement Universal Design for Learning (UDL) and their beliefs. Consequently, Griful-Freixenet et al. (2021) concluded that a growth mindset is a key factor in the successful implementation of Universal Design for Learning (UDL). They found that teachers with a growth mindset are more likely to organize meaningful learning activities and utilize strategies that cater to student's diverse needs. This conclusion aligns with Griful-Freixenet et al. (2020), which identified a growth mindset as the second most important predictor of UDL implementation. Preservice teachers who exhibited a stronger growth mindset were more inclined to embrace teaching strategies aligned with the UDL model.

The findings of Griful-Freixenet and her colleagues are supported by other researchers, including Coubergs et al. (2017), Hattie (2012), Leroy et al. (2007), and Trouilloud et al. (2006). Teachers who believe that intelligence is malleable, rather than fixed, tend to employ teaching strategies that account for students' differences in learning, such as interests, readiness, and learning profiles. Furthermore, teachers with a growth mindset adopt more meaningful classroom practices, like cooperative learning, and provide greater support for student autonomy.

These findings suggest that both Differentiated Instruction and UDL are significantly and positively influenced by teachers' growth mindsets. Hence, we propose the following hypothesis:

Hypothesis 2. A growth mindset mediates the relationship between UDL and DI

2.4 The Mediating Role of Ongoing Assessment

In addition to teacher philosophy, teacher practice factors also mattered in implementing DI and UDL (Stanford & Reeves, 2009). The DI-Quest model by Griful-Freixenet et al. (2017) pointed out that ongoing assessment and flexible grouping were the two main classroom practices.

Ongoing assessment is a critical practice in both Universal Design for Learning (UDL) and Differentiated Instruction (DI), involving the use of outputs from classroom interactions, tasks, behavior, and conversations to inform and adapt teaching practices (Gheysens et al., 2021; Hattie, 2012). This continuous process of feedback helps students understand their current performance, track their progress, and set future learning goals. By providing real-time insights into student learning, ongoing assessment allows teachers to adjust their instructional strategies to better meet the diverse needs of their students (Cai & Lombaerts, 2024).

The importance of ongoing assessment is underscored by its role in differentiated instruction. Empirical studies have shown that ongoing assessment is crucial for DI because it enables teachers to tailor their teaching methods and materials to the individual needs of students (Griful-Freixenet et al., 2017). This adaptability is central to the principles of DI, which aim to provide personalized learning experiences that cater to students' varying levels of readiness, interests, and learning profiles.

Moreover, ongoing assessment aligns closely with the principles of UDL, which emphasize the need for flexible and responsive teaching practices. By continuously assessing student performance and adjusting instruction accordingly, teachers can create more inclusive learning environments that accommodate the diverse learning needs of all students.

Given the theoretical and empirical support for the role of ongoing assessment in both UDL and DI, we propose the following hypothesis:

Hypothesis 3: Ongoing assessment mediates the effect of UDL on DI.

2.5 The Mediating Role of Flexible Grouping

Flexible grouping means students can have positive group conversion, in other words, they can change between working with homogeneous and heterogeneous groups (Tomlinson et al., 2003). The form of homogeneous allowed students to decide the pace of their progression considering their competencies, and students in the heterogeneous group would help them develop together. For example, highly advanced learners could provide additional help to lower-achieving learners (Hoferichter et al., 2022; Tomlinson et al., 2003). This dynamic grouping strategy is underpinned by the principles of differentiated instruction, which aim to address the diverse needs of students by tailoring educational experiences to their varying levels of readiness, interests, and learning profiles.

Research substantiates the effectiveness of flexible grouping. For instance, Aliakbari and Haghghi (2014) found that students engaged in flexible grouping settings performed better in reading comprehension compared to those in traditional teaching environments. This suggests that flexible grouping can lead to improved academic outcomes by providing students with more personalized and supportive learning experiences.

Moreover, flexible grouping has been identified as a critical factor in the successful implementation of differentiated instruction across various educational contexts. In physical education, for example, this practice enables teachers to address the diverse needs of students more effectively. However, appropriate adjustments to curricula, pedagogy, and assessment must be made at the same time to effectively implement DI (Cai & Lombaerts, 2024).

Given its alignment with the principles of UDL, flexible grouping is also seen as a complementary strategy that enhances UDL implementation. UDL aims to create inclusive learning environments that accommodate the diverse needs of all students. Flexible grouping is consistent with UDL's goal of providing equitable learning opportunities by promoting different instructional formats and multiple modes of engagement.

Therefore, we propose the following hypothesis:

Hypothesis 4: Flexible grouping mediates the effect of UDL on DI.

2.6 The Combined Mediating Effects of Flexible Grouping and Ongoing Assessment

Combining flexible grouping and ongoing assessment provides a comprehensive approach to adaptive teaching, which is central to the principles of Universal Design for Learning (UDL) and Differentiated Instruction (DI).

Flexible grouping plays a crucial role in this adaptive teaching model by allowing students to move between homogeneous and heterogeneous groups based on their competencies and needs. This strategy fosters a responsive classroom environment where advanced learners can support their peers, and all students can engage in tasks suited to their readiness levels (Coubergs et al., 2017; Wen & Cai, 2024).

Ongoing assessment complements flexible grouping by providing continuous feedback on student performance. Teachers use this feedback to modify their instructional strategies, ensuring that teaching remains aligned with students' evolving needs. Empirical research has demonstrated that ongoing assessment is a core aspect of DI, enabling teachers to adjust their practices based on student evaluations and behavior (Gheysens et al., 2020; Hattie, 2012).

The integration of flexible grouping and ongoing assessment supports a holistic approach to adaptive teaching. This combination allows teachers to respond effectively to the diverse learning profiles of their students by continuously adapting their instructional methods and group configurations. Griful-Freixenet et al. (2020) found that these practices together foster inclusive education, enhancing the effectiveness of both UDL and DI.

Given the complementary roles of flexible grouping and ongoing assessment in facilitating adaptive teaching, we propose the following hypothesis:

Hypothesis 5: Ongoing assessment and flexible grouping together mediate the effect of UDL on DI.

3. Method

3.1 Participants and Procedure

This study involved a diverse group of 647 in-service teachers from 20 higher education institutions in China, spanning midsize to large cities. These institutions included 5 universities and 15 vocational colleges, representing a broad socioeconomic spectrum, although socioeconomic factors were not explicitly measured. The teacher participants varied in age from 34 to 50 years, with a gender distribution of 58.6% male (379 teachers) and 41.4% female (268 teachers). In terms of professional training, a significant majority, 71.1% (460 teachers), had no experience in Differentiated Instruction (DI) or Universal Design for Learning (UDL), while 28.9% had undergone such training. These questionnaires were administered directly to the in-service teachers at the higher education and vocational institutions.

Ethical protocols were rigorously followed, with approvals from the ethics committees of all participating schools and informed consent obtained from every participant. Data collection utilized both digital and traditional methods: an online survey conducted via WenJuanXing, a Chinese platform, and a paper-based questionnaire. The distribution of these questionnaires was facilitated through WeChat invitations and the assistance of student-teachers, who played a crucial role in logistics and support during the survey process.

These student-teachers, tasked with distributing paper questionnaires, were deployed to the respective schools. Their responsibilities included explaining the study, ensuring anonymity, helping, and informing participants of their right to withdraw at any time. The survey sessions, lasting between 20 to 30 minutes, were conducted in regular classroom settings, maintaining the participants' anonymity. Upon completion, the collected data were digitized and organized into Excel by the student-teachers. It's noteworthy that some teachers declined participation due to time constraints or other commitments.

3.2 Measures

A 10-item independent variable (UDL action scale) was administered from The Inclusive Teaching Strategies Inventory (ITSI) (Lombardi et al., 2015). Mediation variables (growth mindset, flexible grouping, and ongoing assessment) and dependent variable (Differentiated instruction, DI) were adopted from the Differentiated Instruction Questionnaire (DI-Quest) (Coubergs et al., 2017). The ITSI was selected due to its

widespread use in evaluating teacher attitudes and the implementation of inclusive teaching practices based on universal design principles (Bong & Chen, 2024). The DI-Quest, a validated instrument, measures teachers' perceptions of differentiated instruction and their practices. The adopted items from both the ITSI and DI-Quest have satisfactory reliability and validity (Coubergs et al., 2017; Sala-Bars et al., 2024). Specifically, the Cronbach's alpha reliability coefficient for the items from both instruments exceeds .70, and all factor loadings are above 0.60 (Griful-Freixenet et al., 2021), surpassing the .60 threshold recommended by Fornell and Larcker (1981).

Independent variable (UDL)

In this study, we selected the action category since previous studies presented that teachers may not necessarily convert their attitudes into actions (Cook et al., 2009). A sample item is "Use technology so that my course material can be available in a variety of formats (e.g., both digital and printed course materials).

Mediation variables (growth mindset, flexible grouping, and ongoing assessment)

The growth mindset (GM) was to measure teachers' beliefs about learning based on Dweck's (2006) theory with 5 items. One of the items is "The way a teacher teaches influences the intellectual capacities of his students". Flexible grouping (FG) assessed the occurrences of heterogeneous or homogeneous forms of grouping. This subscale contained 8 items such as, "I regularly change between working with homogeneous and heterogeneous groups". Lastly, ongoing assessment (OA) was considered to evaluate the occurrences of using formative and summative assessments to understand the student's learning process, including 4 items like "I use assessment to gain insight into the learning processes of my students".

Dependent variable (Differentiated instruction, DI)

This subscale measured the occurrences of teachers adapting teaching based on students' readiness, learning profiles, and interests. There are 8 items in this construct, for example: "I choose the learning content and teaching methods based on my students". The response of all the above variables ranged from 1 (strongly disagree) to 5 (strongly agree).

4 Data Analysis

Our hypothesized model was tested using structural equation modeling (SEM) via AMOS 23.0, which is well-suited for assessing variable relationships, including mediating effects. We adopted Byrne's (2016) two-step method: initially confirming measurement properties through confirmatory factor analysis (CFA) to ensure construct validity, followed by SEM to examine structural relationships. Fit indices were used to evaluate model adequacy: the chi-square by degrees-of-freedom value (smaller than 3), the comparative fit index (CFI, larger than 0.90), the Tucker–Lewis's index (TLI, larger than 0.90), the root means square error of approximation (RMSEA, smaller than 0.08) and standardized root mean square residual (SRMR, smaller than 0.08). The descriptive statistics were calculated using SPSS 26.0.

For step 2, regarding hypothesis 1, we tested a model that posited a direct relation between UDL and DI. Next, concerning the mediating effects, we adopted a four-step procedure proposed by MacKinnon (2008). Furthermore, specific indirect effects were calculated by user-defined estimand (Ali et al., 2020).

4.1 Descriptive Statistics

Table 2 presents the means, standard deviations, and correlations among the key variables. The results presented that growth mindset, flexible grouping, ongoing assessment, and UDL were positively related to DI ($\gamma = .37, p < .01$; $\gamma = .67, p < .01$; $\gamma = .67, p < .01$; $\gamma = .62, p < .01$ respectively). UDL was also positively related to growth mindset, flexible grouping, and ongoing assessment ($\gamma = .30, p < .01$; $\gamma = .71, p < .01$; $\gamma = .74, p < .01$ respectively).

Table 2*Descriptive Statistics and Correlations for Study Variables (N=647)*

	M	SD	1	2	3	4	5
1. Growth mindset	3.54	.91	(.81)				
2. Differentiated Instruction	3.64	.77	.37**	(.78)			
3. flexible grouping	3.84	.82	.31**	.67**	(.84)		
4. ongoing assessment	3.70	.75	.27**	.67**	.75**	(.84)	
5. UDL	3.99	.81	.30**	.62**	.71**	.74**	(.84)

Note. ** $p < .01$. UDL=Universal Design for Learning; The values in parentheses represent the square root of the Average Variance Extracted (AVE)

5. Results

5.1 Measurement Model

Before testing our hypotheses, CFA was conducted to examine the strength of item loadings, the consistency and reliability of the scales, as well as both convergent and discriminant validity.

Chin (1998) suggests that for robust factor analysis, item loadings on constructs should ideally exceed .70, though a minimum of .60 is acceptable. Hence, we decided to drop the following items from further analyses: UDL (2,3,4,6,7,8,9); DI (1,2,4,5); FG (1,2,6,7,8); GM (1,5); OA1. Furthermore, we followed Fornell and Larcker's (1981) three-measure process to assess the convergent validity of the measurement model: (a) internal consistency reliability, (b) composite reliability of each measure, and (c) the average variance extracted (AVE) of all constructs. Table 3 shows that standardized loadings for the items fell between .63 and .93, which indicates a reliable preliminary measurement. Composite reliability (CR) scores also surpassed the .60 benchmark set by Fornell and Larcker (1981), with values ranging from .85 to .88. Furthermore, the average variance extracted (AVE)

exceeded the .50 minimum, with values between .61 and .71, affirming the measurement model's convergent validity. The values in parentheses referring to the square root of the AVE in Table 2 verify the discriminant validity. This is evident because the square root of the AVE for each construct is greater than its shared correlations with other constructs in the corresponding rows and columns (Fornell & Larcker, 1981).

Table 3*Coefficients for the Measurement Model*

Construct	Variable	S.E.	C.R.	P	STD	Composite reliability	AVE
Differentiated	Dif3				.63	.86	.61
Instruction	Dif6	.08	16.61	***	.84		
	Dif7	.08	16.45	***	.82		
	Dif8	.08	16.43	***	.82		
Flexible grouping	fle3				.85	.88	.71
	fle4	.04	24.88	***	.91		
	fle5	.04	21.46	***	.75		
Ongoing assessment	Out2				.83	.88	.71
	Out3	.04	23.71	***	.86		
	Out4	.04	23.37	***	.84		
UDL	UDL1				.84	.88	.71
	UDL5	.04	23.45	***	.83		
	UDL10	.04	23.99	***	.86		
Growth mindset	Gro2				.74	.85	.66
	Gro3	.06	19.57	***	.93		
	Gro4	.05	18.94	***	.75		

Note. *** $p < .001$. UDL=Universal Design for Learning; STD=Standardized factor loadings

5.2 Hypothesis testing

First, we tested the direct paths between UDL and DI, excluding the mediating variables of growth mindset, flexible grouping, and output input. The structural model indicated a very good fit, $\chi^2 = 13.077$, $df = 13$, $\chi^2/df = 1.0$, CFI = 1.0, TLI = 1.0, RMSEA = .00, SRMR = .01). As shown in Table 3, the correlation coefficients indicated that UDL was positively and significantly related to differentiated instruction ($\gamma = .62$, $p < .01$). In addition, the results of

the direct effect of UDL on differentiated instruction was also statistically significant (standardized direct effect=.71, $p < .001$). Hence, hypothesis 1 was supported.

For testing mediation effects, we followed MacKinnon's (2008) suggestion. Applying it to this study requires (a) a significant relation between the independent variable (UDL) and the dependent variable (DI), (b) a significant association between the independent variable (UDL) and the mediation variables (growth mindset, flexible grouping, and ongoing assessment), (c) a significant association between mediation variables and DI while controlling for the independent variable, and (d) a significant coefficient for the indirect path between UDL and DI through mediation variables. Given the result of hypothesis 1, the condition (a) was already satisfied. Furthermore, the results of the direct effects of UDL on growth mindset (standardized direct effect=.35, $p < .001$), on flexible grouping (standardized direct effect=.31, $p < .001$), on ongoing assessment (standardized direct effect=.84, $p < .001$) were all statistically significant. Therefore, the condition (b) in our model was also supported. Regarding condition (c), the results of the direct effect of growth mindset on DI (standardized direct effect=.15, $p < .001$), flexible grouping on DI (standardized direct effect=.31, $p < .001$), ongoing assessment on DI (standardized direct effect=.38, $p < .001$) were all also statistically significant. For condition (d), we used user-defined estimand to examine the indirect effects and performed percentile bootstrapping and bias-corrected percentile bootstrapping at a 95% confidence interval with 5,000 bootstrap samples (Hayes, 2009; Williams & MaKinnon, 2008). Next, as proposed by Hayes (2009), if zero is not located between the lower level and the upper level of the CI, then an indirect effect is present. The result of the mediation analysis is shown in Table 4. The bootstrap test confirmed the existence of a positive and significant mediating effect between UDL and DI through growth mindset, ongoing assessment, flexible grouping, ongoing assessment, and flexible grouping together. Overall, the four criteria for establishing the mediation effect were completely satisfied. Hence, hypotheses 2, 3, 4, and 5 were supported.

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Table 4

Standardized Direct, Indirect, and Total Effects of the Hypothesized Model

	Point estimate	Product of coefficients		Bootstrapping				
				Bias-Corrected Percentile 95% CI		Percentile 95% CI		Two-tailed significance
				SE	Z	Lower	Upper	
Standardized direct effects								
UDL→DI	0.10	0.08	1.25	-0.05	0.25	-0.06	0.24	0.19
UDL→Growth mindset	0.35	0.06	5.83	0.23	0.45	0.24	0.46	0.00***
UDL→Output input	0.84	0.02	42.00	0.80	0.89	0.80	0.88	0.00***
UDL→flexible grouping	0.31	0.08	3.88	0.16	0.46	0.17	0.46	0.00***
Growth mindset→DI	0.15	0.04	3.75	0.08	0.25	0.07	0.24	0.00***
Output input→flexible grouping	0.58	0.08	7.25	0.43	0.73	0.43	0.72	0.00***
Flexible grouping→DI	0.31	0.08	3.88	0.13	0.45	0.15	0.46	0.00***
Output input→DI	0.38	0.10	3.80	0.19	0.57	0.19	0.57	0.00***
Standardized indirect effects								
UDL→Growth mindset→DI	0.06	0.02	3.00	0.03	0.10	0.02	0.09	0.00***

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UDL→Output input→DI	0.33	0.09	3.67	0.17	0.50	0.17	0.50	0.00 ^{***}
UDL→flexible grouping→DI	0.10	0.04	2.50	0.04	0.18	0.04	0.18	0.00 ^{***}
UDL→Output input→flexible grouping→DI	0.16	0.04	4.00	0.07	0.25	0.07	0.25	0.00 ^{***}
Standardized total effects								
UDL→DI	0.74	0.05	14.80	0.64	0.83	0.64	0.83	0.00 ^{***}

Note. Standardized estimating of 5,000 bootstrap sample, *** $p < .001$, ** $p < .01$, * $p < .05$

UDL=Universal Design for Learning; DI=Differentiated Instruction

6. Discussion

This research formulated a theoretical framework that integrates the principles of universal design theory and philosophy as well as practical theories of DI. Utilizing this framework, the study directly investigated the relationship between Universal Design for Learning (UDL) and DI. Additionally, a mediation model was created to explore the indirect connection between UDL and DI, mediated by practical factors (both individually and collectively) and teachers' growth mindset philosophy.

6.1 Relationship between UDL and DI

This study substantiates a positive correlation between Universal Design for Learning (UDL) and Differentiated Instruction (DI), aligning with previous research that outlines their complementary and embedded relationships (Beasley & Beck, 2017; Katz & Sugden, 2013; Lee & Picanco, 2013; Selmer & Floyd, 2012). The positive association found extends the existing understanding of how UDL and DI interact and support each other within educational settings, demonstrating that their integration is both feasible and beneficial. Our findings are particularly supported by Beasley and Beck (2017), who noted that UDL and DI synergistically enhance each other by tailoring educational approaches to meet varied learner requirements through diverse teaching methods. This study provides empirical evidence that supports their assertion, showing how UDL's framework facilitates

the effective implementation of DI. This enables educators to address the specific needs of all students inclusively and equitably.

Griful-Freixenet et al. (2017) emphasized that both UDL and DI are rooted in the recognition of each learner's uniqueness, necessitating personalized educational assessments and curricula. Our results add depth to this perspective by demonstrating how this theoretical overlap translates into practical outcomes, enhancing DI's effectiveness through UDL's framework.

Lee and Picanco (2013) identified the application of UDL principles—such as multiple means of representation, action, and engagement—as facilitators in achieving DI goals. Our findings corroborate this viewpoint by illustrating how effectively utilizing these principles can foster an inclusive learning environment that supports diverse learning interests, profiles, and readiness levels (Wen & Cai, 2024).

Our results also resonate with the studies of Tobin (2008) and Katz and Sugden (2013), who argue that DI is intrinsically embedded within the UDL framework. Tobin highlights the necessity of universal design in effective literacy courses, while Katz and Sugden show how UDL's Three-Block Model inherently incorporates DI, particularly through instructional practices that accommodate diverse learning needs.

By affirming that UDL and DI aim to meet diverse educational needs through adapted curricula and instructional strategies, this study builds on Selmer and Floyd's (2012) work by demonstrating how UDL-aligned teaching practices can naturally prompt educators to diversify their methods. This finding is crucial as it deepens the understanding of how UDL and DI synergistically work to minimize learning barriers and enhance educational access and equity. This contribution provides valuable insights for educators aiming to create more inclusive and effective learning environments.

6.2 Mediation Roles in UDL-DI Relationship

Crucially, the influence of UDL on DI is entirely mediated by practical factors (both individually and collectively) and the philosophy of a teacher's growth mindset. The subsequent sections will delve into each hypothesis considering this mediation framework linking UDL and DI.

First, the model indicates that the most significant predictor of DI is its mediation through ongoing assessment. This finding aligns with expectations, as previous research has

demonstrated the critical role of ongoing evaluation in tailoring education to students' readiness, learning profiles, and interests (Bi et al., 2023).

The combination of ongoing assessment and flexible grouping emerges as the second most vital factor in predicting the impact of UDL on DI. This finding reinforces the idea of a sequential mediation involving both flexible grouping and ongoing assessment in the relationship between UDL and DI. Consequently, this outcome significantly broadens prior research on the critical roles of both ongoing assessment and flexible grouping in DI (Griful-Freixenet et al., 2017).

Second, our research demonstrates that flexible grouping plays a significant and positive role in mediating the relationship between Universal Design for Learning (UDL) and Differentiated Instruction (DI). This finding directly supports Coubergs et al.'s (2017) assertion that various grouping methods can predict the usage of DI, and that the UDL framework promotes the implementation of flexible grouping among teachers (Selmer & Floyd, 2012).

Last, the connection between UDL and DI is entirely influenced by a growth mindset, aligning with prior studies that emphasize the significant impact of a growth mindset on both UDL and DI (Coubergs et al., 2017; Gheysens et al., 2020; Tomlinson & Imbeau, 2010). Specifically, a growth mindset is recognized as a crucial predictor of effective DI implementation (Coubergs et al., 2017) and is ranked as the second most influential factor affecting UDL implementation by teachers (Griful-Freixenet et al., 2020), corroborating Novak's (2022) findings.

In the framework of UDL, the adoption of a growth mindset is paramount. Educators must view student variability as standard and believe that all students can achieve common educational objectives with adequate support. This perspective is fundamental to the successful application of UDL, driving educators to cultivate an educational environment that seeks to maximize each student's potential by leveraging their strengths and addressing their unique needs (Novak, 2022).

6.3 Implications for Theory

This study reinforces existing research (e.g., Coubergs et al., 2017; Griful-Freixenet et al., 2020 & 2021; Rose & Meyer, 2002) which identifies Universal Design for Learning (UDL) as a critical factor in the successful implementation of Differentiated Instruction (DI). Our findings deepen the understanding of UDL's essential role in enhancing DI effectiveness.

Additionally, our research introduces a nuanced mediation model that suggests the impact of UDL on DI is mediated by both practice factors and a growth mindset. While previous studies (e.g., Beasley & Beck, 2017; Griful-Freixenet et al., 2017 & 2020) have explored the UDL-DI connection, our study uniquely examines the direct and indirect effects of UDL on DI. The direct effects corroborate Lee and Picanco's (2013) advocacy for implementing DI through UDL's core principles: multiple means of representation, action, expression, and engagement. The indirect effects confirm the mediator role of a growth mindset, flexible grouping, and ongoing assessment in the UDL-DI relationship. This insight opens avenues for further theoretical exploration into how psychological and educational factors intertwine within the UDL and DI frameworks, potentially enriching the existing theoretical landscape with new perspectives on these mediating variables.

Further research should replicate this direct and indirect model to assess its relevance in different educational settings and levels. For example, it could also be generalized to different groups of in-service teachers. Such replication would help clarify the concepts of UDL and DI and contribute to developing a unified theory of inclusive education (Griful-Freixenet et al., 2021).

6.4 Implications for Practice

This study builds upon and extends the theoretical insights of Griful-Freixenet et al. (2020), marking a novel exploration of the mediating roles of teacher philosophy, particularly a growth mindset, and practice factors in the relationship between UDL and DI. Utilizing structural equation modeling with AMOS, this research provides valuable insights into teacher instruction, emphasizing the need for ongoing assessment as a critical predictor of UDL's impact on DI.

Feedback dialogue is regarded as an integral part of ongoing assessment strategies (Nicol & Macfarlane-Dick, 2006). This dialogue involves students as both recipients and providers of feedback, facilitating a deeper understanding of teachers' standards and immediate support for learning challenges. Teachers can be encouraged to employ various strategies, including small group feedback discussions and classroom technologies, to enhance this feedback dialogue.

Furthermore, the study validates the significance of flexible grouping in classrooms, as supported by Castle et al. (2005), particularly for students below goal levels. This approach allows for the formation of groups based on common interests and shared tasks,

enhancing learning experiences. Hoffman (2002) suggests various group configurations, including student-led common interest groups, shared task groups, and dyads, each requiring specific instructional and social strategies to optimize learning outcomes.

It's crucial in teacher education to emphasize the development of a growth mindset among teachers, especially since it's identified as a key factor affecting the relationship between UDL and DI. Long-term interventions are essential for cultivating a growth mindset among teachers. Teacher educators should consistently integrate growth mindset theories into their instruction and foster an environment that encourages this mindset during daily interactions with teachers (Tan & Levesque-Bristol, 2024). It is also beneficial for teacher educators to develop a strong growth mindset themselves to effectively model these behaviors. Moreover, encouraging experienced teachers to reflect on their teaching experiences and beliefs can enhance their awareness and mindfulness, helping them sustain adaptive beliefs despite the challenges and pressures of the teaching profession.

Additionally, drawing on insights from Kroeper et al. (2022), teacher educators can actively promote a growth mindset in teachers through four strategies: 1. emphasizing effort value and language guidance: educators should train teachers to value hard work, persistence, and help-seeking as keys to success, rather than innate talent. Additionally, educators should offer guides on how to deliver feedback that reinforces growth, effort, and the educational process. 2. Establishing systems for continuous improvement in schools: schools can establish systems to facilitate regular, constructive, and instant feedback and provide additional resources for practice. This can include access to interactive platforms and additional assignments that support continuous improvement. 3. encouraging positive reactions to challenges: teacher educators should design professional development programs that directly address the challenges teachers face. For example, establishing a peer mentoring program can enable teachers to learn from colleagues who are proficient in these areas. 4. shift value placement towards learning and improvement: teacher educators can encourage schools to create recognition programs that reward improvements in teaching practices and learning outcomes, instead of focusing only on high performance.

7 Limitations

UDL and DI: Mediating Effects of Growth Mindset and Teaching Practices

This research, primarily involving teacher education universities and vocational colleges, suggests a need for broader participant diversity in future studies. Recognizing that school environments significantly influence teachers' philosophies and practices in Differentiated Instruction (DI), as noted by Coubergs et al. (2017), future research should include educators from various academic levels, such as international and primary or secondary schools.

Moreover, while previous studies have acknowledged the relationship between UDL and DI, this study uniquely employs teacher philosophy and practice factors as mediators to integrate these two models. Therefore, replicating this study in different cultural settings could enhance the generalizability of these findings.

Lastly, while acknowledging the importance of demographic variables and other factors like an ethical compass in DI, self-efficacy, self-regulation, motivation for teaching, and attitudes towards UDL, this study did not include them in the proposed model to maintain focus. Future research could explore these aspects as potential mediators or moderators to further understand the dynamics between UDL and DI or examine other facets of these educational frameworks.

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