

Implementing Universal Design for Learning in European preschools: A cross-national analysis of inclusive education

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Abstract

Inclusive early childhood education is a stated policy goal across Europe, yet limited research has examined how Universal Design for Learning (UDL) principles are understood and applied by preschool teachers in different national contexts. This cross-sectional study aimed to investigate how in-service and pre-service early childhood educators in Austria, the Czech Republic, Latvia, and Portugal perceive and implement UDL-aligned practices. A validated survey measured the valuation of the three UDL principles (Multiple Means of Engagement, Representation, and Action & Expression) at both general and detailed levels among 358 in-service and 82 pre-service teachers. The results revealed a significant gap between general endorsement and detailed implementation across all countries and teacher groups, with Portuguese teachers demonstrating no such gap and exhibiting more integrated UDL understanding in network analyses. Significant cross-national differences among in-service teachers reflected the influence of local educational contexts, while their absence among pre-service teachers suggested a shared, experience-free perspective. Perceived lack of training was associated with lower self-assessed competence. The findings suggest that while teacher preparation may successfully instil an inclusive philosophy, it requires greater emphasis on concrete implementation strategies to bridge the gap between general endorsement and practical application across diverse European contexts.

1. Introduction

Inclusive education represents a fundamental policy objective within the European educational landscape, articulated through frameworks including the European Pillar of Social Rights (European Commission, 2021) and the Strategic Framework for European Cooperation in Education and Training (European Union, 2021). This commitment extends to early childhood education and care (ECEC), recognized by UNESCO, the OECD, and the European Union as foundational for lifelong learning and social inclusion. EU-level targets aim for 96% of children from age three to compulsory school age to participate in ECEC by 2030 (Eurostat, 2025), reflecting policy consensus that access constitutes a necessary first step toward inclusion. International organizations including UNESCO, which promotes inclusive education as a fundamental right, the European Union, which drives policy alignment through funding mechanisms, and the OECD, whose international assessments shape national agendas on quality and equity, collectively influence this policy direction (Woodcock et al., 2022).

The preschool period is characterized by significant neuroplasticity, during which foundational brain architecture for cognitive, social, and communication abilities is established (Zhang et al., 2022; Marzola et al., 2023; Chen et al., 2025). Early experiences shape executive functions, emotional self-regulation, and prosocial skills - competencies fundamental for subsequent academic achievement and lifelong inclusion (Sankalaite et al., 2021; Korucu et al., 2022; Muir et al., 2023). While early childhood education enrollment for children from age four was 91.8% in 2009 (European Council, 2009), the Europe 2020 target of 95% for this age group was surpassed by 2019. For children from age three until compulsory primary education, the EU average participation rate was 92.8% in 2019, prompting a new target of 96% by 2030 (European Union, 2021). Among analyzed countries, Latvia demonstrates the highest preschool

enrollment at 95.6%, followed by Portugal at 94.2%. Austria, at 91.2%, performs slightly above the EU average, while the Czech Republic, at 85.3%, faces greater challenges in reaching the 96% target (Eurostat, 2025).

Ensuring access requires attention to meaningful inclusion. Of the world's approximately 2 billion children aged 0–14, an estimated 240 million live with disabilities - a figure likely underestimated due to stigma, limited screening programs, and underdiagnosis (UNICEF, 2023; *Children in the World by Country*, 2025). This diagnostic gap complicates planning for inclusive education and underscores the need for universal design approaches.

Universal Design for Learning (UDL) provides a pedagogical framework addressing this imperative. Grounded in neuroscience, UDL addresses three core brain networks: affective networks (the "why" of learning), recognition networks (the "what"), and strategic networks (the "how") (CAST, 2024). These networks are operationalized through three principles: providing Multiple Means of Engagement to recruit interest and sustain effort; providing Multiple Means of Representation to present information in varied formats; and providing Multiple Means of Action & Expression to differentiate how learners demonstrate knowledge (Meyer et al., 2014). UDL emphasizes proactive curriculum design that anticipates learner variability from the outset (Meyer & Rose, 2025; Centre for Teaching and Learning, 2024). In early childhood education, this translates to flexible environments supporting diverse developmental trajectories, interests, and communication modes.

While the implementation of the UDL framework is intrinsically linked to preschool teacher competence, including pedagogical content knowledge, assessment skills, family collaboration, and the capacity for differentiated instruction, comparative cross-national research on how educators perceive and apply these principles across European systems remains limited (Lakkala & Kyrö-Ämmälä, 2021; Donath et al., 2023). This study addresses this gap by employing a comparative analysis of four strategically selected European contexts, namely Austria, the Czech Republic, Latvia, and Portugal, where ongoing collaborations with local co-authors facilitate to achieve research aims. The objective is to examine and compare how in-service and pre-service early childhood educators across these countries implement and perceive inclusive practices aligned with the UDL framework. The following research questions guide this inquiry:

1. How do in-service early childhood teachers in Austria, the Czech Republic, Latvia, and Portugal perceive the importance of, and to what extent do they report implementing, strategies aligned with the three UDL principles?
2. What UDL-aligned strategies do pre-service early childhood teachers in these four countries consider essential for promoting inclusive practices?
3. What contextual challenges and resources influence teachers' support for UDL principles and their implementation?

2. Theoretical Framework

UDL provides a comprehensive framework for designing inclusive learning environments that accommodate learner variability from the outset. In early childhood education, the three core UDL principles translate into distinct yet interconnected pedagogical practices that support young children's diverse ways of learning and engaging with their surroundings.

The principle of Multiple Means of Engagement targets learners' affective networks and is essential for fostering motivation and sustained involvement in learning. In preschool settings, this principle manifests through strategies that recruit and sustain children's interest, such as offering choices in play activities, incorporating children's special interests into projects, using visual schedules to provide predictability, and cultivating classroom climates where effort and persistence are valued (Author et al., 2025a). These practices align with key UDL checkpoints, including recruiting interest, sustaining effort and persistence, and fostering self-regulation (CAST, 2024).

Multiple Means of Representation addresses recognition networks, focusing on how information is perceived and comprehended. For preschoolers, this means presenting information through multiple modalities, for example, objects, pictures, songs, and gestures. It involves supporting vocabulary development through pre-teaching key words, using symbols alongside text, and activating prior knowledge through discussions and hands-on experiences (Author et al., 2025a). This principle encompasses checkpoints for perception, language and symbols, and comprehension (CAST, 2024).

Multiple Means of Action & Expression targets strategic networks, concerning how learners organize and demonstrate understanding. In early childhood, children may express learning through drawing, building with blocks, dramatic play, singing, or dictating stories. Providing varied means for action includes supporting fine and gross motor skills through different tools and materials and fostering executive functions by helping children plan play, set goals, and self-monitor progress (Author et al., 2025a). Key checkpoints include physical action, expression and communication, and executive functions (CAST, 2024).

Implementation of UDL principles in educational practice depends fundamentally on teacher competence, as educators require pedagogical content knowledge to recognize when children struggle and identify appropriate UDL checkpoints, alongside skills to design flexible lessons offering multiple pathways and collaborative capabilities to work with families and specialists (Chen et al., 2023; Flood & Banks, 2021). While UDL effectiveness in improving learning outcomes is well established, particularly when all three principles are fully implemented (Almeqdad et al., 2023), research on teacher preparation reveals that although teacher candidates readily grasp multiple means of representation and expression, they struggle considerably with designing for engagement, particularly around fostering self-regulation and sustained motivation in learners (Scott et al., 2022). This suggests that effective UDL-focused professional development must move beyond simplistic checklist approaches to instead cultivate flexible pedagogical thinking grounded in deep understanding of learner variability (Lambert et al., 2023; Mackey et al., 2023). Research embedding UDL in practice-based curricula, including STEM-integrated robotics (Barna et al., 2025), bilingual drama-based preschool learning (Kilinc et al., 2025), and inclusive

music education (Anderson & Benson, 2025), demonstrates that actively modeling UDL principles within authentic learning environments significantly enhances teacher preparedness. Furthermore, digital platforms designed with UDL elements can effectively support differentiated learning paths (Roski et al., 2024), while curriculum redesign in higher education demonstrates that UDL can reduce attrition and increase engagement when implemented systematically (Craig et al., 2025; Garrad & Nolan, 2023). Meanwhile meta-analytic evidence confirms large effect sizes for UDL interventions across diverse educational contexts (Almeqdad et al., 2023).

However, much research is situated within single-country contexts. Cross-national comparative perspectives are needed to understand how challenges and competencies manifest across different policy and cultural settings.

2. Methodology

3.1. Instrument Development and Validation

The survey instrument was developed and validated through a pilot study in Latvia with 59 preschool teachers (43 in-service, 16 pre-service) (Author et al., 2025b). The pilot employed reliability analysis using Cronbach's alpha, exploratory factor analysis (EFA) with Kaiser-Varimax rotation, Spearman rank correlation tests, and network analysis. The instrument demonstrated excellent reliability, with Cronbach's alpha of .946. Subscales for the three UDL principles showed strong internal consistency: Engagement Methods ($\alpha = .658 - .856$); Representation Tools ($\alpha = .718 - .875$); Action & Expression ($\alpha = .728 - .809$). Exploratory factor analysis supported a three-factor solution aligned with UDL theoretical structure, though revealing cross-loadings suggesting practical overlap between principles. Correlation and network analyses confirmed significant relationships between all three UDL principles. Key bridging nodes including "Language & Symbols" and "Emotional Regulation" were identified. The pilot confirmed instrument robustness and informed minor refinements to item clarity.

3.2. Translation and Cross-Cultural Adaptation

The validated English-language survey underwent translation and adaptation to ensure cross-cultural validity. Initial translations into German, Czech, Latvian, and Portuguese used DeepL Translate. Each translated version was reviewed by national co-researchers, who refined terminology and phrasing to align with national education systems and professional jargon. This process preserved original construct integrity while ensuring linguistic accuracy and cultural appropriateness. This approach aligns with established protocols for cross-cultural adaptation of UDL instruments (Gäng-Pacifico & Rusconi, 2024).

3.3. Survey Instrument and Structure

The final instrument was a structured questionnaire organized into five sections. The first section gathered demographic and professional background information. A branching question classified respondents as in-service or pre-service teachers, directing them to role-adapted versions of subsequent sections.

A distinctive feature of the survey design was a two-tiered approach to assessing each UDL principle, which in the findings is referred to as the "before" (general) and "after" (detailed) comparison. This terminology reflects the sequential structure of the questionnaire, not a pre-test/post-test intervention design. In the initial demographic section (prior to the core UDL items), respondents completed a general importance rating for each of the three broad UDL principles (Engagement, Representation, Action & Expression) using a single item per principle. Later, in the dedicated sections for each principle, they provided detailed importance ratings for the specific UDL checkpoints underlying that principle (e.g., for Engagement: recruiting interest, sustaining effort, self-regulation). This dual-level design enables a methodological contribution: the examination of whether educators' high-level endorsement of a principle corresponds with an equally robust valuation of its concrete, constituent strategies, thereby revealing potential gaps between philosophical agreement and practical understanding.

Three core sections corresponded to the three UDL principles, evaluating specific checkpoints. To compare enacted practice with perceived necessity, identical checkpoints were presented with adapted phrasing: in-service teachers responded to "I use..." prompts; pre-service teachers rated "A teacher should use..." statements. Responses used a four-point Likert scale (1 = Never, 2 = Sometimes, 3 = Often, 4 = Always). Multiple Means of Engagement was evaluated through 13 items spanning checkpoints for recruiting interest, sustaining effort, and self-regulation. Multiple Means of Representation was assessed via 12 items covering perception, language and symbols, and comprehension. Multiple Means of Action & Expression was measured through 11 items addressing physical action, expression and communication, and executive functions.

The final section investigated practical enablers and barriers to implementing UDL-aligned strategies, maintaining role-adapted framing.

3.4. Participants and Data Collection

Data collection occurred collaboratively from May to September 2025, with national co-researchers responsible for survey dissemination within their countries. The final sample comprised 440 preschool education specialists from Austria, the Czech Republic, Latvia, and Portugal. Table 1 presents a summary of key participant characteristics by country, while the complete demographic data, including detailed information on professional roles, qualifications, and work contexts can be found as Supplementary Table S2 online.

Table 1
Summary of Participant Characteristics by Country (N = 440)

Characteristic	Austria (n = 123)	Czech Republic (n = 108)	Latvia (n = 108)	Portugal (n = 101)
Gender (% Female)	97.6%	98.1%	100%	94.1%
Highest Qualification	Pursuing (34.1%)	Prof. Higher Ed L2 (31.5%)	Bachelor's (46.3%)	Master's (33.7%)
Experience (> 10 years)	48.8%	28.7%	59.3%	70.3%
Work Location	Rural (44.7%)	Metropolitan (77.8%)	Small Town (54.6%)	Small Town (47.5%)
Role: In-service Teacher	60 (48.8%)	63 (58.3%)	82 (75.9%)	83 (82.2%)
Role: Childcare Assistant	0	12 (11.1%)	0	0
Role: Student	37 (30.1%)	28 (25.9%)	8 (7.4%)	10 (9.9%)
Role: Pre-service Teacher	0	5 (4.6%)	18 (16.7%)	8 (7.9%)
Role: Inclusion Educator	26 (21.1%)	0	0	0

The sample was relatively balanced across countries, with slightly higher participation from Austria (27.9%). The preschool education sector is predominantly female across all countries (94.1% in Portugal to 100% in Latvia). Educational qualifications varied by national context. Portugal and the Czech Republic show higher proportions of Master's degrees (33.7% and 28.7% respectively), while Bachelor's degrees are most common in Latvia (46.3%), and a significant portion of Austrian respondents are pursuing qualifications (34.1%). Most respondents, particularly in Portugal (70.3%) and Latvia (59.3%), had over ten years professional experience.

The final participant qualifications reflect structural realities of each national system. To enhance ecological validity, national co-investigators from Austria and the Czech Republic recommended expanding recruitment criteria to include "Childcare Assistant" (Chůva) and "Inclusion Educator" roles. These participants completed the standard teacher questionnaire, as their direct classroom involvement aligned with the study's focus. Consequently, these role categories appear in Austrian and Czech datasets but are not represented in Latvian and Portuguese staffing models. Additionally, the "Pre-service Teacher" category is absent from the Austrian dataset, reflecting divergence in local interpretation and application of this role during sampling. This adaptation captures professional landscapes of each country, strengthening contextual fidelity of cross-national comparison.

3.5. Data Analysis

Data were analyzed using descriptive statistics (Cooksey, 2020). Frequencies were visualized using histograms (Scott, 1992). Kruskal-Wallis H tests compared UDL principle differences among countries (Arifin, 2026). Wilcoxon signed-rank tests examined differences between general importance ratings and detailed importance scores (Welsch & Neuhäuser, 2025). Network analysis using graphical lasso (glasso) procedure was conducted separately for each country to identify relationships between UDL checkpoints and compare cross-national differences (Leme et al., 2020). Centrality plots identified elements with greatest influence on each national network. Analysis used SPSS version 29 and JASP version 0.18.

To ensure data integrity, a systematic approach was adopted for handling non-standard responses. In less than 1% of cases where respondents selected multiple answers per question, final scores were calculated as the rounded average of the selected values, preserving the directional tendency of the response. For items with fewer than five missing responses, missing values were imputed using the median score for that specific question, a method appropriate for ordinal data. The total proportion of data affected by either averaging multiple selections or imputing missing values was below 5%, which is well within acceptable limits for retaining cases in statistical analysis and minimizes the risk of introducing bias (Biemer & Lyberg, 2003; Groves et al., 2009; De Leeuw et al., 2012).

3.6. Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee of Riga Technical University (Protocol Code 04000 – 10.2.3-e/26, date of approval: 28 May 2025). Participant consent was implied through voluntary completion of the anonymous survey, which contained no personally identifiable information.

3. Results

4.1. General Perception of UDL Principles

Educators across all four countries endorsed the importance of the three UDL principles for creating inclusive learning environments. The majority of respondents in each country rated them as "rather important" or "very important." Presenting information using varied materials (Representation) was consistently rated most critical: 61.3% of Latvian and 57.1% of Austrian respondents rated it "very important." Engaging children through diverse methods (Engagement) received high ratings, particularly in Austria, where 77.9% rated it "very important." Expressing and assessing knowledge through various means (Action & Expression) received slightly lower but still positive ratings (e.g., 59.4% in Latvia and 49.5% in the Czech Republic rating it "very important"). Portuguese responses showed greater distribution across the importance scale, with smaller proportions selecting "very important" compared to other countries: Engagement (44.8% in Portugal vs. 77.9% in Austria) and Representation (45.5% in Portugal vs. 61.3% in Latvia).

4.2. Cross-National Differences in UDL Implementation (In-Service Teachers)

Kruskal-Wallis H tests revealed statistically significant differences ($p < .001$) across all nine UDL checkpoints when comparing the four countries. Portuguese in-service teachers reported highest implementation levels across most checkpoints, particularly Action & Expression strategies supporting Executive Functions ($M = 3.35$, $SD = 0.61$) and Representation strategies for Perception ($M = 3.27$, $SD = 0.82$). Austrian teachers demonstrated high implementation for Engagement strategies: Recruiting Interest ($M = 3.31$, $SD = 0.55$) and Sustaining Effort ($M = 3.23$, $SD = 0.47$), and for Physical Action ($M = 3.11$, $SD = 0.72$). Latvian and Czech teachers reported moderate to lower implementation. Czech scores were lowest for several checkpoints: Language & Symbols ($M = 2.36$, $SD = 0.63$) and Physical Action ($M = 2.48$, $SD = 0.67$). Latvian teachers showed moderate implementation, with means ranging from 2.45 (Physical Action) to 3.21 (Sustaining Effort). The complete statistical results, including descriptive statistics and Kruskal-Wallis H test outcomes for in-service teachers across all nine UDL checkpoints can be found as Supplementary Table S3 online.

4.3. Cross-National Differences in Perceived Importance (Pre-Service Teachers)

Kruskal-Wallis H tests showed no statistically significant differences between countries for most UDL checkpoints among pre-service teachers. For Recruiting Interest (Q2_1), $p = .509$; for Sustaining Effort (Q2_2), $p = .073$; for Expression & Communication (Q4.2.), $p = .890$. This homogeneity suggests pre-service teachers, with limited practical experience, share similar idealized understandings of inclusive practice, shaped by teacher education curricula rather than specific national contexts. The exception was Representation checkpoint "Language & Symbols" (Q3.2.), where significant difference was found ($H = 8.646$, $p = .034$), suggesting potential cultural differences in linguistic awareness before entering the profession. Pre-service teachers in all countries expressed high perceived importance, with mean scores above the scale midpoint (3.0). The complete statistical results for pre-service teachers, including descriptive statistics and Kruskal-Wallis H test outcomes can be found as Supplementary Table S4 online.

4.4. General vs. Detailed Importance Ratings

Wilcoxon signed-rank tests revealed significant gaps between general endorsement and detailed importance ratings for in-service teachers in Austria, the Czech Republic, and Latvia ($p < .001$ for all three principles). For Austrian in-service teachers, general endorsement of Engagement (transformed mean = 0.94) was significantly higher than detailed ratings of specific engagement strategies (mean = 0.73). The pattern was more pronounced for Representation: general endorsement (means 0.83–0.86) compared to detailed ratings (means 0.54–0.60). For Action & Expression, Latvian teachers showed the largest discrepancy (general mean = 0.87, detailed mean = 0.58, $p < .001$).

Portuguese in-service teachers showed no significant gap between general and detailed importance ratings for any UDL principle (Engagement: $p = .891$; Representation: $p = .163$; Action & Expression: $p = .075$).

This gap was also observed among pre-service teachers in Austria, the Czech Republic, and Latvia ($p < .05$). Portuguese pre-service teachers showed no significant gap.

The complete results of the Wilcoxon signed-rank tests, including detailed statistics for all participant groups across all three UDL principles, can be found as Supplementary Table S5 to S10 online.

4.5. Overall distribution and structural relationships of UDL importance ratings

To visualize the overall distribution of UDL importance ratings and assess cross-national patterns in valuation consistency, aggregated scores combining general and detailed items were examined for each principle. These distributions, presented in Supplementary Figures S1-S3, provide visual confirmation of the patterns identified through statistical testing.

For Multiple Means of Engagement (Supplementary Figure S2), importance scores were left-skewed across all countries, indicating generally high valuation. Portugal demonstrated the highest mean (3.40) and smallest standard deviation (0.40), suggesting more uniformly high and consistent valuation of engagement strategies among Portuguese educators. Austria ($M = 3.13$, $SD = 0.46$), the Czech Republic ($M = 3.07$, $SD = 0.44$), and Latvia ($M = 3.09$, $SD = 0.42$) showed similar distributions with slightly lower means and greater spread.

For Multiple Means of Representation (Supplementary Figure S3), greater cross-national variation was evident. Portugal again showed a left-skewed distribution with a high mean (3.33, $SD = 0.56$). Distributions for Austria ($M = 2.78$, $SD = 0.53$), the Czech Republic ($M = 2.70$, $SD = 0.51$), and Latvia ($M = 2.80$, $SD = 0.46$) were more normal or slightly right-skewed with lower means, indicating more moderate valuation of representation strategies outside Portugal.

For Multiple Means of Action & Expression (Supplementary Figure S4), a similar pattern emerged. Portugal maintained a left-skewed distribution with high mean (3.33, $SD = 0.56$). Austria ($M = 2.97$, $SD = 0.47$) and Latvia ($M = 2.74$, $SD = 0.49$) showed different means, while the Czech Republic had the lowest mean (2.79, $SD = 0.53$) for this principle. These distributions confirm that Portuguese educators demonstrate not only higher average valuation of UDL principles but also greater consensus in their ratings.

4.6. Structural Relationships: Centrality and Network Analysis

To examine how the nine UDL checkpoints interrelate within each national context, centrality analysis and network graphs were constructed based on detailed importance ratings (see Supplementary Figures

S4 and S5). These analyses reveal distinct national patterns in how pedagogical concepts are structured.

Centrality plots (Supplementary Figure S4) visualize the relative influence of each UDL checkpoint within its national network. In Austria and the Czech Republic, centrality is distributed across multiple nodes, with checkpoints from Multiple Means of Engagement (Q2.1-Q2.3) and Multiple Means of Action & Expression (Q4.1-Q4.3) being particularly prominent. This distribution suggests a balanced conceptual model where no single element dominates, but integration across principles remains moderate.

Latvia demonstrates a more focused centrality structure. The specific checkpoint "Language & Symbols" (Q3.2) from the Representation principle, together with Engagement checkpoints "Recruiting Interest" (Q2.1) and "Self-Regulation" (Q2.3), emerge as key linking hubs. This indicates that these elements are perceived as central connectors within Latvian educators' understanding of inclusive practice, potentially serving as bridges between different UDL dimensions.

Portugal displays the most distinctive pattern, with a tightly interconnected cluster particularly evident within the Action & Expression principle (encompassing all its checkpoints Q4.1-Q4.3). This reflects a highly cohesive and integrated perception where specific strategies are seen as fundamentally linked and central to the conceptual framework of UDL.

Network graphs (Supplementary Figure S5) provide complementary visualization of these interrelationships. Austrian and Czech networks show three relatively discernible clusters corresponding to the three UDL principles, yet with several strong bridging connections, particularly between Engagement and Representation clusters (e.g., between "Sustaining Effort" and "Language & Symbols"). This indicates that while educators conceptually separate the principles, their perceived implementation involves strategies that functionally span them.

Latvia's network displays tighter integration between Engagement and Action & Expression clusters, suggesting a pedagogical emphasis on linking motivational support with expressive opportunities. Portugal presents the most densely interconnected and cohesive network, with robust edges linking all three principle clusters into a unified web. Across all networks, checkpoints related to sustaining effort (Q2.2), comprehension (Q3.3), and expression (Q4.2) consistently emerge as central hubs with the highest number of strong connections, underscoring their perceived foundational role in inclusive practice.

4.6. Challenges and Support Structures

Teachers identified "lack of resources" and "time constraints" as most frequent obstacles. Teachers citing "Limited knowledge or training opportunities" as primary challenge reported lowest self-assessed competence scores, particularly for Representation ($M = 2.70$) and Action & Expression ($M = 2.74$) (see Supplementary Table S11). This aligns with literature identifying insufficient training as key barrier to UDL implementation (Chen et al., 2023; Flood & Banks, 2021).

Teachers reporting "Resistance from colleagues or institution" had highest self-assessed competence scores across all three UDL principles (UDL1: M = 3.26; UDL2: M = 3.02; UDL3: M = 3.02).

Analysis of relationship between professional development support received and self-assessed competence showed statistically significant relationship only for Engagement principle ($p=.005$) (see Supplementary Table S12). Teachers reporting "Other" forms of support had highest self-assessed competence for Engagement (M = 3.34). No significant variation was found for UDL2 and UDL3 based on support type.

4. Discussion

This comparative study set out to examine how in-service and pre-service early childhood educators across four European countries perceive and implement practices aligned with the Universal Design for Learning framework. The findings reveal complex patterns of convergence and divergence that address each of the three research questions while contributing to the growing body of literature on UDL implementation in early childhood education. The discussion that follows synthesises these patterns, considering their implications for teacher education, educational policy, and future research.

The first research question concerned how in-service teachers perceive the importance of and report implementing UDL-aligned strategies. The most striking finding in this regard is the consistent discrepancy between educators' general endorsement of UDL principles and their valuation of the specific pedagogical strategies that operationalise these principles. This "importance-implementation gap" was observed across Austria, the Czech Republic, and Latvia, with Portuguese educators representing a notable exception to this pattern. This discrepancy warrants careful consideration of how UDL is currently conceptualised and taught in teacher preparation programmes. The gap resonates with previous research indicating that while teacher candidates readily grasp the philosophical underpinnings of inclusive education, they struggle considerably with translating these principles into concrete pedagogical actions (Scott et al., 2022; Mackey et al., 2023). Lambert and colleagues (2023) argued that effective UDL-focused professional development must move beyond checklist approaches to cultivate what they term "a way of thinking" grounded in deep understanding of learner variability. The present findings suggest that current approaches may be succeeding at the philosophical level but falling short at the practical level.

The pattern was particularly pronounced for the Representation principle, where general endorsement was high but detailed ratings were substantially lower across Austria, the Czech Republic, and Latvia. This suggests that while educators readily accept the importance of presenting information through varied modalities, they may lack confidence in the specific strategies this entails - such as supporting vocabulary development through pre-teaching, using symbols alongside text, or activating prior knowledge through discussions and hands-on experiences. This interpretation is consistent with research by Chen and colleagues (2023), who found that Australian secondary teachers reported positive attitudes toward UDL but limited practical knowledge of implementation strategies. For Action &

Expression, Latvian teachers showed the largest discrepancy between general and detailed ratings, suggesting particular challenges in this domain within the Latvian context despite the country's high preschool enrollment rates and centralized education system. These cross-national variations in which principles show the largest gaps provide important clues about where professional development efforts might be most urgently needed in each context.

The finding that significant cross-national differences emerged among in-service teachers across all nine UDL checkpoints provides a clear answer to the first research question regarding the influence of national context. Portuguese in-service teachers consistently reported the highest implementation levels, particularly for Action & Expression strategies supporting Executive Functions and Representation strategies for Perception. Austrian teachers demonstrated strong implementation for Engagement strategies, including Recruiting Interest and Sustaining Effort, as well as for Physical Action. Latvian and Czech teachers reported moderate to lower implementation, with Czech scores lowest for Language & Symbols and Physical Action. These patterns suggest that national educational systems, policies, and resources substantially shape how UDL principles are enacted in daily classroom practice, even when educators across countries share similar underlying values about inclusion.

The second research question addressed the strategies pre-service teachers consider essential for promoting inclusive practices. Here the findings are particularly instructive. Kruskal-Wallis H tests showed no statistically significant differences between countries for most UDL checkpoints among pre-service teachers, with the sole exception of "Language & Symbols." This homogeneity suggests that pre-service teachers across these four countries share remarkably similar idealized understandings of inclusive practice, shaped by teacher education curricula rather than specific national contexts. While this common grounding provides a valuable foundation, it also raises questions about whether pre-service teachers are adequately prepared for the contextual realities they will encounter in their specific national settings. The challenge for teacher educators is to design programmes that simultaneously provide a coherent theoretical foundation and prepare future teachers for the diverse contextual conditions they will encounter.

The exception of "Language & Symbols" is noteworthy. The significant cross-national difference for this checkpoint suggests that cultural and linguistic awareness may begin to form before teachers enter the profession, potentially reflecting deeper cultural orientations toward language and communication that are transmitted through teacher education. This finding aligns with research embedding UDL in practice-based curricula across diverse contexts, including STEM-integrated robotics in Ukraine (Barna et al., 2025), bilingual drama-based preschool learning in the United States (Kilinc et al., 2025), and inclusive music education in the United Arab Emirates (Anderson & Benson, 2025). These studies demonstrate that while UDL principles can be effectively modeled across different settings, their specific manifestation is inevitably shaped by local linguistic and cultural conditions.

The "importance-implementation gap" observed among pre-service teachers in Austria, the Czech Republic, and Latvia, and its absence among Portuguese pre-service teachers, provides additional

insight into the second research question. This pattern suggests that the disconnect between general ideals and specific practices may begin to form during initial teacher education, before teachers have accumulated significant classroom experience. The Portuguese exception indicates that it is possible to design teacher preparation that fosters more integrated understanding, where philosophical commitment and practical strategy knowledge develop together rather than separately.

The third research question concerned the contextual challenges and resources that influence teachers' support for UDL principles and their implementation. The analysis of implementation challenges revealed important relationships between perceived obstacles and self-assessed competence. Teachers who cited "limited knowledge or training opportunities" as their primary challenge reported the lowest self-assessed competence scores, particularly for representation and action & expression. This finding underscores the critical importance of high-quality professional development and suggests that current offerings may be insufficient for developing teacher confidence in these areas. The consistency of this finding across multiple UDL principles and the alignment with previous research (Chen et al., 2023; Flood & Banks, 2021) suggests a genuine need for enhanced professional learning opportunities focused on concrete implementation strategies.

The finding that teachers reporting "resistance from colleagues or institution" had the highest self-assessed competence scores is particularly intriguing. This pattern may reflect a form of institutional resistance to innovation, wherein educators who are most committed to inclusive practices encounter disproportionate barriers as their efforts challenge established norms and routines (Miller, 2024; Paulsrud, 2024). Alternatively, successfully navigating resistance may itself strengthen teacher self-efficacy. This interpretation has implications for school leadership. Rather than viewing teacher reports of resistance simply as complaints, school leaders might recognise them as potential indicators of a motivated and innovative workforce whose efforts are being hindered by systemic obstacles. Through shared vision-building, collaborative planning, and provision of adequate resources may enable these pioneering teachers to more effectively implement inclusive practices.

The analysis of professional development support revealed that only for the Engagement principle was there a statistically significant relationship between support type and self-assessed competence. Teachers reporting "other" forms of support, likely indicating diverse, collaborative, and context-sensitive approaches, had the highest self-assessed competence for Engagement. This finding provides important guidance for professional development design. It suggests that formal courses and structured programmes may be less effective for developing engagement competencies than more flexible approaches such as mentoring relationships, professional learning communities, and action research projects. These approaches offer the kind of sustained, practice-embedded support that enables teachers to develop confidence in engagement strategies, which research has consistently identified as the most challenging UDL principle to implement (Scott et al., 2022; Mackey et al., 2023). Studies demonstrating the effectiveness of practice-based UDL curricula (Barna et al., 2025; Kilinc et al., 2025; Anderson & Benson, 2025) similarly emphasise the value of authentic learning environments for developing teacher competence.

Across all countries, engagement strategies emerged as an area of particular complexity. While general endorsement of the engagement principle was high, detailed ratings for specific engagement checkpoints showed substantial variation, and the "importance gap" for engagement was significant in all countries except Portugal. The network analysis provided additional insight into this challenge. Checkpoints related to sustaining effort consistently emerged as central hubs across all national networks, suggesting that educators recognise this element as foundational to inclusive practice. Yet the lower detailed ratings indicate that translating this recognition into confident implementation of specific strategies remains difficult. This difficulty may reflect the inherently complex nature of engagement as a pedagogical construct, requiring ongoing responsiveness to children's affective states, interests, and motivations.

Several limitations of this study should be acknowledged when interpreting its findings. First, the reliance on self-reported data means that responses may be subject to social desirability bias, with teachers potentially overestimating their implementation of socially valued inclusive practices (Van de Mortel, 2008; Lüke, & Grosche, 2018). Future research should complement self-report data with observational measures that capture actual classroom practice, building on methodological approaches such as the UDL Observation Measurement Tool (Gäng-Pacífico & Rusconi, 2024) or structured observation protocols (Author et al., 2025a). Second, the cross-sectional design captures a snapshot of teacher perceptions at a single point in time and cannot establish causal relationships between variables. Longitudinal studies tracking teachers over time, particularly following pre-service teachers into their early careers, would provide valuable insights into how perceptions and practices develop and how the "importance-implementation gap" may be narrowed through experience and professional support. Third, while the sample of 440 participants across four countries provides robust comparative data, the uneven distribution of pre-service teachers across countries warrants caution in interpreting some subgroup comparisons. Future research with larger and more balanced pre-service samples would enable more confident cross-national comparisons among this group. Fourth, the study focused on teacher perceptions rather than child outcomes. While teacher competence is undoubtedly important, understanding how UDL implementation actually affects children's learning and development requires research designs that include child-level outcome measures. Such research would provide evidence about the ultimate effectiveness of UDL-aligned practices and could inform decisions about resource allocation and professional development priorities. Fifth, the cultural and linguistic adaptation of the survey instrument, while rigorous, cannot fully capture all nuances of how UDL principles are understood and enacted across different national contexts. Future research might employ qualitative methods, including interviews, focus groups, and classroom observations, to develop deeper understanding of how educators in different countries conceptualise inclusive practice and the factors that shape their approaches.

Several directions for future research emerge from these findings. Detailed comparative analysis of teacher education curricula across countries could identify specific program features associated with more integrated UDL understanding. Such research might examine how UDL is taught, the extent to which programmes provide practice-based opportunities for developing specific competencies, and how

these features relate to graduate outcomes. Research examining the relationship between UDL implementation and child outcomes across different national contexts would provide evidence about whether the patterns observed in teacher perceptions translate into meaningful differences in children's learning and development.

5. Conclusions

This study provides comparative evidence on how UDL principles are perceived and implemented by preschool educators across four European countries, offering several conclusions relevant to research, policy, and practice that address the study's overarching aim of examining cross-national similarities and differences in inclusive practices.

The identification of a consistent "importance-implementation gap" across Austria, the Czech Republic, and Latvia reveals a significant challenge for inclusive education. While educators universally endorse UDL principles at an abstract level, their valuation of specific implementation strategies is substantially lower. This gap, which addresses the first and second research questions concerning how in-service and pre-service teachers perceive and implement UDL, suggests that current teacher preparation and professional development may successfully communicate the philosophy of inclusion but fall short in developing the practical competencies required for confident implementation. Addressing this gap requires moving beyond philosophical advocacy toward intensive, practice-based professional learning that builds procedural knowledge and self-efficacy.

The profound influence of national context on in-service teachers' reported implementation, contrasted with the homogeneity among pre-service teachers, highlights the role of educational systems in shaping practice. This finding directly addresses the first research question regarding in-service teachers while also speaking to the comparative dimension of the study's aim. Teacher education programmes across countries may impart relatively standardised visions of inclusive practice, but these visions are transformed by the realities of local contexts. This underscores the importance of supporting beginning teachers as they navigate the transition from idealised preparation to contextualised practice, and suggests that national policies and resources significantly influence what inclusive education looks like on the ground.

Engagement emerges as the most challenging UDL principle for educators across all countries, with persistent difficulties in translating general endorsement into confident implementation of specific strategies. This finding addresses the first and second research questions regarding which strategies are considered essential and implemented, while also speaking to the study's aim of identifying cross-national patterns. The association between diverse, collaborative professional support and higher engagement competence suggests that developing this capacity requires more than formal training - it requires ongoing, context-sensitive opportunities for learning and reflection within supportive professional communities.

The relationship between perceived knowledge limitations and lower self-assessed competence underscores the critical importance of high-quality professional development. This finding directly addresses the third research question concerning challenges and resources, while also contributing to the study's overall aim of understanding factors that influence effective implementation. Teachers who feel underprepared to implement UDL principles cannot be expected to do so effectively, regardless of their philosophical commitment to inclusion. Investing in professional learning that builds both knowledge and confidence must be a priority if the promise of UDL is to be realised in practice.

In conclusion, this study achieves its aim of examining and comparing how in-service and pre-service early childhood educators across different European contexts implement and perceive inclusive practices aligned with the UDL framework. The findings reveal that translating the promise of UDL into reality for all young learners requires a dual focus: fostering deep, systemic commitment to inclusive philosophy while simultaneously cultivating granular, practical mastery of its methods. This work must be undertaken at multiple levels—in teacher education programmes that prepare future educators, in professional development that supports practising teachers, in policy frameworks that enable coherent practice, and in school cultures that value and support inclusive approaches. Only through such multi-level, coordinated effort can the vision of universally designed learning environments be realised across diverse European contexts.

Declarations

Data Availability

The anonymised datasets, survey instruments, and analysis scripts supporting the findings of this study are available in the Zenodo repository under the accession link provided below. The following materials have been deposited:

- Anonymised raw dataset (combined across all four countries) [filename: raw_data_anonymised.csv]
- Processed dataset (aggregated scores used in statistical analyses) [filename: processed_data_aggregated.csv]
- Survey questionnaires (English, German, Czech, Latvian, and Portuguese versions) [filename: questionnaires_multilingual.pdf]
- Codebook (variable definitions and coding schemes) [filename: codebook_UDL_study.pdf]
- Statistical analysis scripts (SPSS syntax and JASP output) [filename: analysis_scripts.zip]

Zenodo repository link (public access for reviewers):

.[INSERT YOUR ZENODO DOI]

The complete dataset and all supporting materials are also available as Supplementary Information files accompanying this manuscript.

Competing interests

The authors declare no competing interests.

Informed Consent

Informed consent was implied through the voluntary completion of the anonymous survey, which contained no personally identifiable information. All participants were informed about the purpose of the study and their right to withdraw at any time before submitting the survey.

Author Contribution

Author Contributions: Conceptualization, I.T., D.B., G.L., L.D. Methodology, I.T., D.B., G.L., L.G. Software, I.T., G.L. Validation, I.T., D.B., G.L. Formal Analysis, I.T., D.B., L.D. Investigation, I.T., L.G., D.K., E.A., M.A.B. Writing—Original Draft Preparation, I.T. Writing—Review and Editing, I.T., D.B., G.L., L.D., L.G., D.K., E.A., M.A.B. Visualization, I.T., G.L. Supervision, D.B., G.L., L.D., L.G., D.K., E.A., M.A.B. Project Administration, I.T., D.B. All authors have read and agreed to the published version of the manuscript.

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