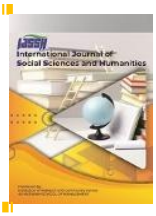

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Development of an Adaptive Visual-Hybrid Learning Model Based on Universal Design for Learning to Improve the Self-Regulated Learning of Deaf Students in Special Senior High School

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Abstract

Self-regulated learning (SRL) is important for deaf students because upper secondary education requires greater independence in planning, monitoring, and evaluating learning. This pilot study developed and tested an adaptive visual-hybrid learning model grounded in Universal Design for Learning (UDL) for deaf students at SLB Negeri Kota Metro. A quasi-experimental nonequivalent control group design was used with 11 students in experimental and control classes. The intervention combined visual supports, captioned and text-based materials, flexible online-offline access, accessible task pathways, and guided self-monitoring activities. Data were collected through an SRL questionnaire, classroom observation, and documentation. The experimental group showed higher improvement than the control group, with mean scores increasing from 62.45 to 82.30 compared with 63.10 to 71.25. The gain scores were 0.53 and 0.22, respectively, and the independent-samples t-test indicated a statistically significant between-group difference ($t = 4.87$, $p < 0.05$). The findings suggest that visually accessible hybrid instruction aligned with UDL may support stronger SRL among deaf learners in this setting.

Contents

Introduction

Inclusive education has moved from a policy aspiration to an operational expectation in contemporary schooling. Learners with disabilities are entitled not only to school access, but also to

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instruction that is understandable, usable, and empowering within everyday classroom practice. In deaf education, this requirement is particularly important because access barriers are often produced by the instructional environment itself rather than by learners' intellectual capacity. When classroom communication relies heavily on fast speech, minimally supported lecture delivery, or unstructured tasks, deaf students are placed in a position where they must work harder merely to obtain information before they can even begin to learn from it. Research on Universal Design for Learning (UDL) consistently argues that these barriers should be anticipated in advance and addressed through proactive instructional design rather than through late, individual accommodation alone (Al-Azawei et al., 2016; Choi & Seo, 2024; Dalton et al., 2019; N. O. Mangelep, 2017).

For deaf learners, educational access is inseparable from visual access. Learning becomes more effective when information is represented through visually organized media, explicit cues, and flexible pathways for revisiting content. The Oxford Handbook of Deaf Studies in Learning and Cognition emphasizes that deaf learners often benefit from instructional conditions that reduce language ambiguity, foreground visual structure, and provide sufficient time for conceptual consolidation. In digital and blended settings, these needs become even more salient because students must coordinate multiple channels of information, such as captions, teacher explanations, slides, graphics, and written tasks. If these supports are poorly designed, technology can increase cognitive burden; if they are purposefully designed, technology can expand participation and independence (Domu & Mangelep, 2023).

At the senior high school level, the need for independence is stronger than in earlier grades. Academic tasks are more complex, schedules are less tightly guided, and students are increasingly expected to plan, monitor, and evaluate their own learning. These processes are commonly discussed under the concept of self-regulated learning (SRL). Contemporary reviews show that SRL is one of the strongest predictors of academic persistence and achievement in online and blended environments because students must decide when to study, how to allocate attention, and how to respond when difficulties arise (N. Mangelep et al., 2020; Prasse et al., 2024; Wong et al., 2019; Xu et al., 2023). For deaf students, SRL is doubly important: it supports academic performance while also helping learners compensate for environments that are not always fully communicative or accessible.

Although SRL is often treated as an internal learner trait, it is strongly shaped by instructional design. Students regulate their learning more successfully when they receive clear goals, predictable routines, meaningful feedback, and accessible options for practice and self-assessment. Reviews of online and blended learning consistently show that supportive design features such as scaffolded feedback, segmented materials, task transparency, and learner choice improve monitoring and persistence (Chen, 2024; Domu & Mangelep, 2019). In other words, SRL grows when classrooms teach students how to regulate, not merely when teachers expect them to regulate. This principle is especially relevant in special education contexts, where access barriers may suppress the appearance of independence even when learners have strong potential.

Hybrid and blended models provide a useful framework for this challenge because they combine face-to-face interaction with flexible digital access. Graham (2019) describes blended learning as a thoughtful integration of physical and digital learning spaces, and later studies have shown that this flexibility can benefit students with disabilities when course structures remain coherent and accessible. Qualitative studies of hybrid learning among students with special education needs report that learners value efficient access, safe participation, and the ability to revisit material, but they also experience uncertainty when expectations are vague or when digital tasks are not clearly adapted to their needs (Fabula, 2023; Rachmawati et al., 2022). In deaf education, these strengths and limitations suggest that

hybrid learning should not be implemented as a simple mixture of offline and online activities; it should be intentionally designed around accessibility and learner agency.

UDL offers a robust framework for that intentional design. The literature portrays UDL as a planning framework that assumes learner variability as the norm and therefore encourages multiple ways of presenting content, engaging students, and allowing them to act on or express their learning (Al-Azawei et al., 2016; Almeqdad et al., 2023; Carrington et al., 2020). Recent research has moved beyond general advocacy and begun to document how UDL can shape lesson design, online course structures, instructor practice, and student experiences. Studies in higher education and online learning demonstrate that instructors are more likely to adopt UDL when they understand it as a practical design process rather than as an abstract ideal (Rao, 2021; Westine et al., 2019)). For learners with disabilities, UDL has been associated with clearer access routes, higher engagement, and more flexible participation.

The relevance of UDL for deaf and hard-of-hearing learners has become more explicit in recent publications. Taylor & Yuknis (2023) showed that UDL supported distance learning for deaf students by strengthening structure, access, and communication. Levesque et al. (2024) further argued that UDL offers a pathway to greater independence for deaf and hard-of-hearing learners because it reduces reliance on one rigid instructional pathway. Gehret & Elliot (2025) found that deaf and hard-of-hearing students using asynchronous multimedia tutorials valued segmenting, visual clarity, and control over playback, all of which align with UDL-informed and multimedia-learning principles. These studies suggest that deaf learners benefit when instruction allows them to control pacing, revisit information, and interact with visually coherent learning materials.

Even so, a practical gap remains in school-based implementation, particularly in special senior high school contexts in Indonesia. Much of the recent literature focuses on higher education, general disability access, or systematic reviews of UDL implementation. Fewer studies report how a teacher-designed, visual-dominant, hybrid model can be developed and tested directly with deaf students at the secondary level. Indonesian studies during and after the pandemic indicate that deaf learners and inclusive classrooms can benefit from digital and hybrid arrangements, yet they also show the continuing need for adaptive media, teacher preparedness, and stronger instructional structures (Mabruroh et al., 2022; Mudrika et al., 2024; Rachmawati et al., 2022). This context makes it necessary to move from broad inclusion discourse toward a concrete, classroom-ready model.

The present study addresses that need by developing an adaptive visual-hybrid learning model based on UDL for deaf students at the senior high school level at SLB Negeri Kota Metro. The model combines visual supports, flexible online-offline access, structured reflection, and differentiated learning pathways to support students' SRL. Conceptually, the model assumes that when accessible representation, guided engagement, and meaningful choice are integrated into hybrid instruction, students may become more capable of planning learning activities, monitoring progress, and completing tasks independently. The study therefore examines whether the model is associated with stronger SRL outcomes than conventional instruction in this pilot context.

This article makes three contributions. First, it translates recent UDL and hybrid-learning scholarship into a concrete intervention suited to deaf secondary learners. Second, it presents pilot evidence from a quasi-experimental implementation using pretest-posttest comparisons and classroom observation. Third, it offers design implications for special schools and inclusive settings seeking to move beyond reactive accommodation toward instructional environments that actively cultivate independence. In this sense, the study is not only concerned with score improvement, but also with the

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design of learning conditions in which deaf students can participate, persist, and regulate their learning with greater confidence.

Methods

This study employed a quantitative approach with a quasi-experimental nonequivalent control group design. The study was conducted at SLB Negeri Kota Metro, Indonesia, at the senior high school level for deaf students. This design was selected because the research was implemented in an authentic school setting where existing classroom groups could not be randomly reorganized. The participants were 11 deaf students selected through purposive sampling based on specific criteria, namely students with hearing impairment, active participation in classroom learning, and basic visual literacy to engage with text, images, and screen-based materials. The sample was divided into an experimental class and a control class according to the existing school arrangement. The experimental class received the adaptive visual-hybrid learning model based on Universal Design for Learning (UDL), while the control class received conventional instruction. Both groups completed pretest and posttest measures of self-regulated learning (SRL). The independent variable was the adaptive visual-hybrid UDL model, while the dependent variable was students' SRL, which referred to students' ability to plan learning activities, monitor task completion, regulate effort, and reflect on learning outcomes.

Table 1. Quasi-experimental design used in the study

Group	Pretest	Treatment	Posttest
Experimental class	T1	Adaptive visual-hybrid UDL model	T2
Control class	T1	Conventional instruction	T2

The research procedure consisted of preparation, implementation, and evaluation. In the preparation stage, the researcher mapped learning objectives, prepared visual and digital materials, and aligned learning activities with UDL principles. In the implementation stage, the experimental class received face-to-face instruction supported by visual organizers, captions, digital reinforcement tasks, and self-monitoring prompts, while the control class received conventional instruction. The model emphasized visual clarity, flexible access, and gradual development of independent learning by using concise written cues, infographics, captions, visual organizers, and segmented digital tasks to reduce cognitive load and support learning accessibility (Gehret & Elliot, 2025; Mayer, 2020). Data were collected through questionnaire, observation, and documentation. The main instrument was an SRL questionnaire based on three dimensions, namely planning, monitoring, and self-reflection, using a five-point Likert scale. The instrument was validated through expert review and empirical testing. Observation sheets were used to record persistence, punctuality, learning initiative, access to materials, and independence during learning. Data were analyzed using descriptive statistics, gain scores, normality and homogeneity tests, and an independent-samples t-test. Observation and documentation data were used as contextual evidence to support the interpretation of quantitative findings

Table 2. Core syntax of the adaptive visual-hybrid learning model

Phase	Instructional focus	UDL emphasis	Contribution to SRL
1. Orientation and goal setting	Teacher introduces goals, timeline, and success criteria using concise written cues and visual agenda displays.	Engagement	Supports forethought by clarifying expectations and activating readiness.
2. Multimodal visual presentation	Core concepts are delivered through face-to-face explanation supported by text, captions, graphics, and visual organizers.	Representation	Reduces ambiguity and helps students plan how to follow the lesson.
3. Guided hybrid practice	Students complete structured tasks in class and through digital reinforcement activities with clear step-by-step prompts.	Action and expression	Strengthens monitoring during task performance and encourages help-seeking.
4. Flexible independent completion	Students revisit captioned or text-based materials and complete assignments through accessible offline-online pathways.	Engagement + Action	Builds time management, persistence, and independent task completion.
5. Reflection and feedback	Teacher provides brief feedback; students review work, note difficulties, and identify next steps.	Engagement	Develops self-reflection and adjustment for subsequent learning.

Results and Discussions

1. Results

a. Descriptive Findings

The first set of findings concerns descriptive changes in SRL before and after the intervention. Both groups showed improvement from pretest to posttest, but the magnitude of change was notably different. The experimental group's mean score increased from 62.45 on the pretest to 82.30 on the posttest, whereas the control group's mean score increased from 63.10 to 71.25. These raw changes suggest that ordinary classroom experience may support some development over time, while the adaptive visual-hybrid UDL model was associated with larger gains. The gain score for the experimental class was 0.53, categorized as moderate to high, while the control class reached 0.22, categorized as low.

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Within the limits of the present sample, this pattern suggests that the intervention supported stronger learning regulation.

Viewed at the construct level, the score pattern implies improvement across the three broad domains of SRL. In the experimental class, students became more capable of preparing for tasks, following learning sequences, and evaluating their work after completion. During implementation, students showed better anticipation of what needed to be done, relied less on repeated teacher prompting, and more often returned independently to digital materials when clarification was needed. These behaviors are consistent with a shift from externally driven task completion toward more deliberate self-management. In the control class, improvement was present but less visible in terms of independence, suggesting that access to instruction alone is not sufficient to strengthen SRL without explicit design support.

Table 3. Comparison of pretest and posttest SRL scores

Group	Pretest (Mean)	Posttest (Mean)	Gain Score	Category
Experimental	62.45	82.30	0.53	Moderate–High
Control	63.10	71.25	0.22	Low

b. Hypothesis Testing

Inferential testing reinforced the descriptive picture. The independent-samples t-test yielded a t-value of 4.87 with a significance value of 0.000, lower than the 0.05 threshold. Accordingly, the null hypothesis was rejected. The finding indicates that the difference in SRL outcomes between students who learned through the adaptive visual-hybrid UDL model and those who learned through conventional instruction was statistically significant. Even within a small pilot sample, the analysis provides an initial indication that the learning model was associated with stronger posttest performance.

Observation data helped explain why the experimental group improved more strongly. Students in the intervention class were more active in accessing materials, more consistent in managing study time, and more independent in completing assigned tasks. Because the hybrid materials remained available beyond the face-to-face lesson, students could review explanations at their own pace and return to tasks after clarification. The use of visual instructions and segmented learning resources also reduced confusion during transitions from one activity to the next. In practical terms, the model appeared to reduce the amount of energy students had to spend decoding the classroom format, leaving more cognitive resources available for learning regulation.

Table 4. Independent-samples t-test result

Description	Value
t value	4.87
Sig. (2-tailed)	0.000
Significance level	0.05
Decision	H0 rejected

2. Discussion

The observed gains can be interpreted through the lens of UDL. Multiple means of representation were visible in the use of visual summaries, text support, infographics, and structured multimedia. These supports likely improved comprehension and reduced ambiguity, both of which are crucial in deaf education. Multiple means of action and expression were reflected in flexible task pathways and opportunities to complete work through guided offline and online formats. Multiple means of engagement were embedded in accessible pacing, repeated access, and feedback-rich routines. Rather than treating these principles as separate features, the model operationalized them as a coherent instructional sequence designed to help students anticipate, act, and reflect more independently.

The findings are consistent with previous studies showing that UDL-informed environments can improve accessibility and learner participation. Recent meta-analytic evidence suggests that UDL instruction has a positive effect on learner achievement when compared with business-as-usual conditions (King-Sears et al., 2023). Systematic reviews similarly conclude that UDL is most effective when it is implemented as a full design framework rather than as a narrow set of accommodations (Almeqdad et al., 2023; Eriyanti et al., 2022; Utami et al., 2025). The present study adds a context-specific indication that, in a deaf secondary-school setting, UDL may also be linked to the development of SRL, a variable that is central to long-term academic autonomy.

The results also align with recent scholarship on deaf learners and accessible multimedia. Taylor & Yuknis (2023) noted that UDL helped structure distance learning for deaf students during periods of disrupted schooling. Levesque et al., (2024) argued that UDL opens a pathway to independence precisely because it supports learners in accessing information through more than one route. Gehret & Elliot (2025) found that deaf and hard-of-hearing students value segmenting, control over playback, and clear visuals in asynchronous tutorials. The current study reflects similar dynamics. Students in the experimental class benefited from the ability to revisit instruction, use visual supports to maintain orientation, and continue learning outside the immediate teacher-led explanation.

From an SRL perspective, the model appears to have strengthened all three cyclical phases of regulation. In the forethought phase, students were supported by clear learning goals, visible task sequences, and structured orientation. In the performance phase, they were supported by accessible materials, digital repetition, and concrete prompts that helped them monitor progress. In the self-reflection phase, they were supported by task review and explicit feedback that encouraged them to evaluate results and adjust future action. Contemporary reviews of SRL in online and blended contexts emphasize that learners do better when supports are distributed across the entire regulation cycle rather than concentrated only at the beginning or the end (Prasse et al., 2024; Xu et al., 2023). The current model appears to have worked in that way within this pilot implementation.

Another important implication concerns the relationship between accessibility and independence. Sometimes educational practice assumes that providing more support will make students dependent. The present findings suggest a different possibility: when support is designed to increase clarity, choice, and control, it may reduce dependence on constant teacher intervention. Visual organizers, captioned resources, and repeatable online materials did not replace students' responsibility; instead, they appeared to enable students to exercise responsibility more effectively. This is consistent with the broader UDL literature, which frames support not as simplification for a few, but as improved design for learner variability as a whole (Rao & Meo, 2016).

The hybrid dimension of the model was also pedagogically significant. Research on blended learning shows that flexibility alone does not automatically improve outcomes; what matters is the quality of integration between modalities (Graham, 2019). In this study, online resources were directly tied to classroom goals rather than functioning as disconnected add-ons. Students knew why the online

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materials mattered, when to use them, and how they related to classroom learning. This coherence likely contributed to improved monitoring behavior. By contrast, hybrid systems that lack clear structure can create uncertainty and undermine self-regulation, especially for students who already face communication barriers (Fabula, 2023).

Nevertheless, the study also points to implementation challenges. Effective visual-hybrid instruction requires more than digital devices; it requires teachers who can organize accessible materials, anticipate communication barriers, and design meaningful transitions between offline and online activities. Studies on UDL readiness repeatedly show that teachers need stronger preparation and ongoing support to implement such models consistently (Alquraini & Rao, 2020; Westine et al., 2019). In the present context, limitations related to school infrastructure, internet access, and teacher training remain important considerations for wider adoption.

The study has several limitations. The sample was small and taken from a single special school, so the results should be interpreted carefully. The SRL measure focused on overall learning regulation and did not isolate which specific subdimensions improved most strongly. In addition, the study emphasized immediate post-intervention outcomes and did not track whether the SRL gains were maintained over longer periods. Future research can therefore expand the sample, compare multiple disability groups or school levels, and integrate mixed-methods evidence such as interviews, platform analytics, or repeated follow-up assessment.

Despite these limitations, the present findings have practical relevance for school practice. They suggest that deaf students' independence may be strengthened when instruction is organized around visual access, hybrid flexibility, and UDL coherence. For teachers, the implication is to move from content delivery toward accessible design. For schools, the implication is to view infrastructure and teacher development as part of inclusion rather than as separate technical issues. For researchers, the implication is that SRL deserves greater attention in deaf education because it links access, participation, and long-term academic agency. In that sense, the adaptive visual-hybrid UDL model can be read not only as an intervention for one school context, but also as a design proposition for more equitable learning environments.

Conclusion

This study suggests that the adaptive visual-hybrid learning model based on Universal Design for Learning was associated with improved self-regulated learning among deaf students at SLB Negeri Kota Metro. The experimental group demonstrated stronger improvement than the control group in both descriptive and inferential terms, with a gain score of 0.53 compared with 0.22 and a statistically significant between-group difference ($t = 4.87$, $p < 0.05$). Within the limits of this pilot study, the model appears promising because it combines three elements that are rarely integrated in routine practice: visual accessibility, hybrid flexibility, and explicit scaffolding of self-regulation.

The instructional significance of the model lies in its potential to accommodate learner variability while fostering independence. Visual supports, repeatable digital materials, and structured feedback did not merely make learning easier; they made it more manageable for students to plan, monitor, and evaluate their own work. This finding reinforces the argument that inclusive design and learner autonomy can be mutually supportive. When classroom environments reduce avoidable barriers, students can invest more attention in regulating learning rather than simply trying to keep up with inaccessible instruction.

For educational practice, the study recommends that teachers in special and inclusive settings use UDL as a lesson-design framework, particularly when planning hybrid instruction for deaf learners.

Schools should support this effort through technology provision, accessible media development, and professional learning related to visual pedagogy and UDL implementation. Future studies should test the model across broader samples, different grade levels, and longer intervention periods in order to refine its components and examine long-term effects. Overall, the study indicates that a carefully designed visual-hybrid model may contribute not only to access, but also to the development of more self-directed and resilient learners.

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