# Reimagining Assessment in Secondary Education through Adaptive, Process-Based ICT

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## Abstract

*Secondary education systems are increasingly challenged to support diverse learner pathways while responding to accelerating social, technological, and economic change. Traditional assessment models—largely centred on time-based progression and high-stakes terminal examinations—often provide limited insight into how learning develops over time and may disadvantage learners whose trajectories are non-linear or who require iterative feedback. This paper presents Phlow Academy as an example of how information and communication technology (ICT) can be used to reframe assessment and progression in secondary education.*

*Phlow Academy is a digital-first learning and assessment platform designed to support adaptive, merit-based progression through continuous evidence of learning. Grounded in Flow Theory, mastery learning, and formative assessment, the platform embeds assessment within everyday learning interactions rather than treating it as a discrete evaluative event. Learner responses generate real-time diagnostic information that informs feedback, scaffolding, and adaptive task sequencing. This approach supports engagement, persistence, and conceptual understanding while promoting learner agency and self-regulation. The system is currently piloted in Junior Cycle Mathematics, with a scalable architecture designed to support additional levels, subjects, and modalities.*

*A distinguishing contribution of the Phlow model is its emphasis on process-based assessment. Rather than privileging final answers alone, the platform captures indicators of procedural reasoning, revision behaviour, and conceptual stability. The paper further extends this model through Learn-AR, a conceptual augmented reality framework that enables adaptive support and formative assessment during pen-and-paper learning. By interpreting handwritten work and verbal reflection in real time, Learn-AR preserves the cognitive value of handwriting while extending feedback beyond screen-based interaction.*

*Together, these elements illustrate how ICT can function as a core infrastructure for assessment reform rather than a supplementary instructional tool. By integrating theory-led design, adaptive analytics, and multimodal interaction, Phlow Academy demonstrates a practical pathway toward more equitable, personalised, and instructionally useful assessment systems in secondary education, aligned with contemporary policy priorities and future learning needs.*

## 1. Introduction

Secondary education systems internationally are under increasing pressure to adapt to rapid social, technological, and economic change. Over the past two decades, the pace of transformation in work, communication, and knowledge production has accelerated, with forecasts suggesting that the rate of change over the coming twenty years will be even more pronounced. In this context, education systems designed around stable curricula, linear progression, and episodic assessment are increasingly misaligned with the capabilities learners will require in adulthood. These include adaptability, self-directed learning, problem-solving, and the capacity to engage in continuous skill development across changing roles and environments [20].

In Ireland, secondary education remains largely structured around time-based progression and high-stakes terminal examinations, most notably the Junior Cycle and Leaving Certificate. While these assessments provide standardised benchmarks and serve important certification functions, they primarily evaluate outcomes at fixed points in time. As a result, they often offer limited insight into how learning develops, how misconceptions are resolved, or how learners respond to challenge and feedback [1,2]. Research has shown that such systems can disadvantage students who progress at different paces, require iterative support, or experience anxiety under exam conditions [17]. Moreover, feedback from terminal assessments typically arrives too late to meaningfully influence learning trajectories.

Phlow Academy was developed in response to these limitations, positioning information and communication technology (ICT) as a core

infrastructure for learning and assessment rather than a supplementary delivery tool. Phlow is a digital-first learning and assessment platform that reconceptualises progression as a dynamic, merit-based process shaped by demonstrated understanding rather than time spent in a programme. Grounded in educational psychology and assessment theory, the platform integrates real-time feedback, scaffolded micro-learning, and adaptive progression into a coherent system designed to support learner agency and sustained engagement.

Rather than separating instruction and assessment, Phlow embeds formative assessment into every learner interaction. Each response—correct, incorrect, or incomplete—generates diagnostic information that informs immediate feedback and future task selection. This approach aligns with extensive research demonstrating that continuous, low-stakes assessment combined with timely, actionable feedback can significantly improve learning outcomes, motivation, and self-regulation [6,18]. By treating assessment as an ongoing source of evidence rather than a periodic judgement, Phlow seeks to shift the role of assessment from sorting learners to supporting learning.

The platform is explicitly theory-led. Flow Theory informs the adaptive modulation of challenge to sustain engagement [4], mastery learning underpins progression based on demonstrated understanding rather than arbitrary timelines [5], and formative assessment principles guide feedback and diagnostic design [6]. These theoretical foundations are operationalised through technical design choices such as micro-progressions, adaptive sequencing, and probabilistic mastery indicators. In this way, Phlow illustrates how educational theory can be embedded directly into digital infrastructure rather than applied retrospectively.

A distinguishing feature of the Phlow model is its emphasis on process-based evidence of learning. Traditional assessment systems typically privilege final answers, obscuring the reasoning pathways, revisions, and metacognitive decisions that underpin understanding. Phlow's data architecture is designed to capture richer indicators of learning, including procedural sequencing, error patterns, time-on-task, and learner interaction behaviours. When extended through emerging modalities such as audio interaction and augmented reality, this approach enables assessment to encompass both digital and pen-and-paper learning contexts, preserving the cognitive value of handwriting while providing timely, personalised support.

Phlow also adopts a multimodal approach to learning and assessment, integrating mobile interaction, audio-only learning, voice-based reflection, and, in development, AR-supported pen-and-paper work. This ecosystem acknowledges that learners engage with and demonstrate understanding in diverse ways, and that inclusive assessment systems must accommodate multiple modes of expression. By drawing on a shared progression and data model, these modalities function as complementary pathways rather than fragmented tools.

Within the Irish context, Phlow aligns closely with national policy priorities articulated in the Digital Strategy for Schools to 2027, which emphasises learner-centred pedagogy, formative assessment, and data-informed teaching [21]. It also responds to ongoing discussions led by the National Council for Curriculum and Assessment regarding the future of assessment and progression in post-primary education. While not positioned as a replacement for summative assessment, Phlow offers a practical model for reducing the disproportionate weight placed on terminal exams by embedding robust formative evidence throughout the learning process.

This paper presents Phlow Academy as an example in how ICT can act as a catalyst for assessment reform in secondary education. By integrating theory-led design, adaptive technology, and process-oriented evidence of learning, the platform illustrates how digital systems can support more equitable, personalised, and instructionally useful approaches to assessment and progression.

## 2. Theoretical Foundations: Flow, Mastery, and Adaptive Formative Assessment

Phlow Academy is grounded in well-established educational theories that have been operationalised through its digital infrastructure to support effective, equitable, and scalable learning. These pedagogical foundations are not only widely supported within the research literature, but also align closely with Ireland's ongoing curriculum and assessment reform agenda, particularly in relation to learner autonomy, assessment for learning, and meaningful integration of digital technologies [1,2]. Rather than adopting technology as an add-on to existing practices, Phlow is designed as a theory-led system in which pedagogy determines technological function.

The platform is targeted primarily at post-primary students between the ages of approximately 12 and 18. This cohort represents not only learners within the current education system, but also the future adult population who, within two decades, will occupy critical roles in a rapidly evolving social and economic landscape. Forecasts of future work consistently highlight increased demand for self-directed learning, initiative-taking, adaptability, and problem-solving in environments where roles are fluid and hierarchies less rigid. [3] In this context, the development of learner autonomy during

adolescence is not simply an educational concern, but a societal one. Phlow is designed to cultivate habits of independent learning, reflection, and persistence at an early stage, reframing the role of the teacher from primary knowledge provider to learning coach and mentor. ICT platforms such as Phlow can support this shift by handling adaptive delivery and diagnostic feedback, thereby freeing educators to focus on higher-level guidance and relational support.

At the core of Phlow's design lies Flow Theory, first articulated by Csikszentmihalyi [4]. Flow describes a psychological state of deep engagement in which individuals are fully immersed in an activity, experiencing focused attention, intrinsic motivation, and a distorted sense of time. Crucially, flow emerges when challenge is appropriately matched to skill. If tasks are too easy, boredom results; if too difficult, anxiety and disengagement follow. In traditional classrooms, maintaining this balance for diverse learners simultaneously is extremely challenging, as instruction is often calibrated to an assumed "average" level of ability.

Phlow addresses this limitation by using real-time learner data to dynamically adjust task difficulty and support. Rather than delivering a fixed sequence of content, the platform continuously calibrates challenge based on learner performance, ensuring that tasks remain within a productive zone of difficulty. This adaptive modulation allows students to experience sustained engagement while avoiding the frustration or complacency that can arise in static instructional models. Research has shown that learning environments that support flow are associated with greater persistence, deeper conceptual understanding, and improved motivation [4]. By embedding flow principles into its digital architecture, Phlow seeks to make optimal engagement achievable at scale.

A second foundational pillar of the platform is Mastery Learning, which advocates for progression based on demonstrated understanding rather than time spent on content [5]. In mastery-oriented systems, learners are provided with sufficient opportunities, feedback, and support to achieve a defined level of competence before advancing. Empirical research suggests that mastery learning can significantly reduce achievement gaps and improve long-term retention, particularly when combined with formative feedback and corrective instruction [5].

Phlow operationalises mastery learning through a system of structured levels and micro-progressions. Each level is composed of scaffolded steps that gradually increase in complexity, ensuring that prerequisite knowledge is secure before more demanding concepts are introduced. Progression is not determined by completion alone, but by accumulated evidence of understanding across multiple interactions. This design acknowledges that learning is rarely linear and that temporary setbacks or misconceptions are a natural part of the learning process. By allowing learners to revisit concepts and stabilise understanding before advancing, Phlow promotes confidence and conceptual coherence rather than superficial coverage.

Formative assessment constitutes the third major theoretical foundation of the platform. Extensive research demonstrates that continuous, low-stakes assessment paired with timely, actionable feedback can have a substantial impact on learning outcomes [6]. Unlike summative assessments, which typically occur after instruction and serve primarily evaluative purposes, formative assessment is embedded within the learning process itself, shaping instruction and supporting learner reflection.

In Phlow, assessment is not a discrete event but an ongoing diagnostic process. Every learner's response—whether correct or incorrect—is treated as informative. The system analyses patterns in errors, response times, and revision behaviour to infer levels of understanding and uncertainty. Feedback is delivered immediately and is tailored to the nature of the learner's difficulty, whether procedural, conceptual, or strategic. This tight feedback loop supports the development of metacognitive skills, encouraging learners to monitor their own understanding and regulate their learning strategies [7].

Central to this process is the use of real-time learner data. Phlow collects fine-grained interaction data, including which steps learners answer correctly, where they struggle repeatedly, how long they spend on specific tasks, and how they respond to feedback. When a learner consistently struggles with a particular concept, the system responds by providing additional scaffolding, alternative explanations, or targeted practice. Conversely, when a learner demonstrates stability and fluency within a subtopic, the platform can introduce more challenging or higher-stage tasks to maintain engagement.

Over time, this data contributes to the construction of learner profiles that reflect not only current performance, but patterns of learning behaviour. These profiles are informed both by individual learner data and by aggregated insights drawn from learners with similar characteristics. As the platform is used by a growing population, its capacity to personalise instruction improves, enabling more accurate predictions of which supports or challenges are likely to be effective for different learner types. This collective learning mechanism reflects broader trends in adaptive educational systems, where scalability enhances rather than dilutes personalisation [14].

Phlow's approach differs fundamentally from conventional e-learning platforms, many of which primarily digitise static instructional content and rely

on linear progression models. Traditional platforms often present identical materials to all learners, with limited capacity to adapt in response to learner behaviour beyond simple branching. In contrast, Phlow is designed as a multimodal learning ecosystem that integrates multiple forms of interaction and representation.

The core mobile application supports visual, interactive, and problem-based learning through touch-based tasks and immediate feedback. The proposed Learn-AR extension further expands this ecosystem by enabling adaptive support during pen-and-paper learning, preserving the cognitive benefits of handwriting while extending formative feedback beyond the screen. In addition, Phlow introduces a planned audio-only learning mode inspired by spaced, narrative-driven learning system. This mode consists of approximately 100 short, structured audio units, each around 30 minutes in duration, designed to introduce and reinforce Phlow subtopics through guided explanation, recall, and reflection.

Audio-based learning offers an inclusive ICT pathway for learners who benefit from verbal processing or who may have limited access to screens. It also supports learning during activities such as commuting or physical movement, reinforcing concepts through repeated, low-pressure exposure. By weaving mathematical ideas in a structured, conversational manner, this approach aligns with flow principles and provides an additional modality through which learners can engage with content.

Together, these theoretical foundations—flow, mastery learning, formative assessment, and multimodal adaptive design—inform a learning environment that prioritises deep understanding, learner agency, and long-term capability development. As ICT becomes increasingly embedded within Irish classrooms, Phlow Academy illustrates how theory-driven design can shape digital learning systems that are not only pedagogically robust, but also aligned with broader societal and policy goals.

## 3. From Static Curriculum to Adaptive Learning Infrastructure: The Phlow Academy Model

Phlow Academy was developed in response to a convergence of challenges facing contemporary secondary education: inequitable progression models, over-reliance on summative assessment, and limited systemic support for learners with diverse abilities and learning trajectories. These challenges are not new; however, the pace at which social, technological, and economic conditions are changing has accelerated dramatically over the past two decades. Forecasts of future work suggest that the next twenty years will see even greater disruption, with increased emphasis on adaptability, self-direction, problem-solving, and initiative-taking in environments characterised by fluid roles and reduced hierarchical structures. Within this context, traditional instructional models—largely designed for industrial-era stability—are increasingly misaligned with the skills and dispositions learners will require.

As a result, reform in how students are taught, assessed, and supported is no longer a matter of innovation for its own sake, but a structural necessity. Phlow Academy responds to this need by reconceptualising ICT not as a supplementary tool, but as a core learning infrastructure capable of supporting continuous adaptation, personalised progression, and learner agency at scale. The platform is currently in early deployment, with Junior Cycle Foundation Mathematics (Levels 1–4) fully developed, and additional levels, subjects, and modalities actively in development.

Crucially, Phlow is designed as an open pedagogical framework rather than a single application. Any ICT activity that aligns with its core ideology—mastery-based progression, formative feedback, learner autonomy, and human-centred support—can be integrated into the ecosystem. This enables the simultaneous development of multiple learning interfaces, including a mobile application, an augmented reality (Learn-AR) layer, and audio-only learning modes, all drawing from a shared data and progression model.

### 3.1. Platform Architecture and Multimodal Content Design

Phlow Academy is implemented as a mobile-first application, reflecting the widespread availability of smartphones among post-primary students in Ireland and internationally [8]. Mobile delivery allows learners to engage with content flexibly across contexts, supporting both structured study and informal learning moments. The platform integrates a content engine with a planned real-time analytics layer, enabling personalised instruction driven by continuous learner interaction data.

Content is organised into scaffolded levels, with each level functioning as a coherent learning unit composed of multiple, interrelated tasks. These units are designed to prioritise cognitive process over answer production, aligning with research that emphasises the importance of reasoning, strategy, and conceptual coherence in learning. Each unit typically includes:

**3.1.1 Multi-Step Problem Sequences**. Multi-Step Problem Sequences rather than presenting isolated questions, Phlow structures tasks as multi-step

problem sequences that mirror authentic problem-solving processes. Learners are guided through intermediate reasoning steps, representations, or decisions before arriving at a final solution. This approach supports procedural fluency while simultaneously revealing where misunderstandings emerge, allowing the system to respond diagnostically rather than evaluatively.

**3.1.2 Interactive, Touch-Based Elements** Interactive, Touch-Based elements allow learners to manipulate values, select options, construct representations, or test hypotheses through direct engagement. Touch-based interaction supports exploration and reduces cognitive friction, enabling learners to focus on underlying concepts rather than interface complexity. Immediate system responses reinforce correct reasoning or redirect attention when errors occur.

**3.1.3 Branching, Context-Sensitive Feedback** Branching, Context-Sensitive Feedback within Phlow is adaptive rather than binary. Responses vary depending on whether a learner demonstrates a common misconception, partial understanding, or a breakdown in procedural sequencing. When incorrect answers are selected, learners experience a brief red screen flash—designed as a low-stakes signal rather than a punitive response—followed by targeted guidance. Research supports the use of such feedback-rich, non-punitive environments to promote persistence, confidence, and willingness to engage with challenges [9].

Importantly, Phlow supports multiple layout and navigation models, allowing learners to engage with content in ways that suit their goals, preferences, or readiness. Three primary modes are currently supported conceptually:

**3.1.3i Level-Based Progression View.** Learners progress through a defined level, answering a fixed number of questions proportional to the level number (e.g., 10 questions in Level 1, 40 in Level 4). Completion is visualised through star-based indicators reflecting mastery across individual Phlows (subtopics). This mode supports structured progression and clarity of expectations.

**3.1.3ii Topic-Centred Exploration View.** Learners engage with Phlows grouped by topic rather than level, encountering tasks of varying difficulty within a single conceptual area. Progress is again tracked through stage completion and star indicators, allowing learners to deepen understanding within a topic before advancing in overall difficulty.

**3.1.3iii Personalised Adaptive Pathway.** In the personalised mode, learners begin with the simplest tasks and are rapidly advanced through levels and Phlows as evidence of understanding accumulates. Each subsequent task is selected algorithmically based on prior performance, error patterns, and response stability. This mode exemplifies Phlow's core philosophy: progression determined by demonstrated ability rather than predefined sequencing.

Together, these architectural choices enable Phlow to function not merely as a learning app, but as a flexible learning infrastructure capable of supporting diverse learner journeys within a unified pedagogical framework.

## 3.2. ICT-Driven Level Progression, Personalisation, and Data Use

Phlow Academy's progression model is explicitly designed to move away from time-based advancement toward merit-based progression grounded in demonstrated understanding. Drawing on mastery-aligned learning systems [10], learners advance through content by accumulating evidence of competence rather than by completing predefined schedules or meeting arbitrary deadlines. This approach reflects research indicating that progression models tied to mastery can support equity, reduce frustration, and better accommodate learner variability.

Each level within Phlow contains a number of questions proportional to its difficulty (for example, 30 questions in Level 3), with tasks algorithmically sequenced to manage cognitive load and support gradual increases in complexity [11]. At present, all levels remain accessible to all learners, allowing open exploration and self-directed challenge. In future implementations, access to higher-difficulty Phlows will be contingent upon demonstrated readiness, ensuring that progression reflects capability rather than aspiration alone.

Central to this model is the systematic use of learner interaction data. Rather than relying solely on correctness, Phlow analyses multiple dimensions of learner behaviour to construct a richer picture of understanding. Planned data points include:

**3.2.1. Error pattern analysis.** Patterns of incorrect responses are analysed to identify recurring misconceptions at specific procedural or conceptual steps. This allows the system to distinguish between superficial slips and deeper misunderstandings, enabling targeted scaffolding rather than generic repetition.

**3.2.2. Time-on-task and Temporal Signals.** Time spent on individual steps or tasks is used as an indicator of fluency or struggle. Extended pauses, rapid guessing, or repeated revisions provide insight into learner confidence and cognitive load, supporting adaptive pacing and intervention.

**3.2.3. Completion and Persistence Indicators.** Completion rates highlight points at which learners disengage or plateau. These indicators are used to refine content design and to adjust challenge levels to sustain engagement and maintain alignment with flow principles.

**3.2.4. Concept mastery indicators.** Rather than binary pass/fail outcomes, Phlow maintains probabilistic mastery indicators that evolve as evidence accumulates. Concepts may be classified as secure, emerging, or unstable, reflecting the dynamic nature of learning rather than a static snapshot.

Importantly, these data serve multiple stakeholders without collapsing into a single evaluative metric. Teachers can use dashboards to identify learners who may benefit from additional support or extension, adapt pacing, or group students strategically. Researchers and curriculum designers can analyse aggregated data to identify systemic gaps or misalignments. Learners themselves benefit from a learning environment in which challenge and support are continuously calibrated, supporting sustained engagement and progression.

Over time, Phlow's data model supports the development of learner typologies based on interaction patterns and learning trajectories. Insights drawn from learners with similar profiles inform future recommendations, enabling the system to improve personalisation as usage scales. This collective learning mechanism reflects broader trends in adaptive educational systems, where increased participation enhances rather than dilutes personalisation [12].

## 3.3. Feedback Loops and Emerging ICT Extensions

Preliminary user testing and design iteration have underscored the importance of smooth transitions, intuitive navigation, and adaptive difficulty in sustaining learner motivation—findings consistent with broader research on user experience in educational technology [13]. Building on this foundation, Phlow Academy is designed to accommodate emerging ICT modalities that extend feedback and assessment beyond conventional screen-based interaction.

Planned ICT enhancements include:

**3.3.1. AI-driven diagnostic and Adaptive Supports.** Planned AI-driven diagnostics will allow Phlow to analyse learner responses in real time, refining feedback and progression decisions as evidence accumulates. Drawing on research into intelligent tutoring systems, these diagnostics are intended to augment rather than replace pedagogical judgement, supporting adaptive instruction while preserving transparency and interpretability [14].

**3.3.2. Audio-Only Learning and Voice Interaction.** In addition to visual and interactive modalities, Phlow introduces an audio-only learning mode inspired by structured language learning systems such as Pimsleur. This mode consists of approximately 100 short audio units, each around 30 minutes in duration, designed to introduce and reinforce Phlow subtopics through guided explanation, recall, and reflection.

Audio-based learning supports inclusion by offering an alternative pathway for learners who benefit from verbal processing or who have limited access to screens. It also enables learning during movement or transit, reinforcing concepts through repeated, low-pressure exposure. Voice interaction tools can be used alongside these audio units, allowing learners to ask questions, articulate reasoning, or request clarification, thereby transforming passive listening into active engagement.

**3.3.3. Conversational and Generative AI Interaction.** Phlow also supports conversational AI interaction similar to chat-based systems, enabling learners to engage in written dialogue about the tasks they are working on. This interaction is designed to remain contextual and task-specific, discouraging reliance on external sources that may bypass learning. In addition to text, generative tools may produce images or short video explanations tailored to the learner's immediate problem, providing multimodal clarification in real time.

These interactions form part of the diagnostic data stream, contributing evidence about learner understanding, misconceptions, and metacognitive engagement rather than serving as shortcuts to answers. [15].

**3.3.4. Learn-AR: AR-Supported Pen-and-Paper Learning.** A significant extension of the Phlow ecosystem is the Learn-AR concept, which integrates augmented reality to support adaptive learning during pen-and-paper work. Despite the growth of digital platforms, handwriting remains central to learning in mathematics and science, supporting conceptual understanding, spatial reasoning, and memory. However, most digital systems cease to provide feedback once learners move off-screen.

Learn-AR addresses this gap by enabling minimal, context-sensitive support while learners work on physical materials. Students wear lightweight AR glasses that interpret handwritten work and recognise the type of task being attempted. When appropriate, brief visual cues, audio prompts, or reflective questions appear discreetly, offering scaffolding without interrupting cognitive flow. Learners can also request help verbally or explain their reasoning aloud.

Crucially, Learn-AR preserves the core features of the mobile platform, including multi-step problem sequences and mastery-aligned progression. As learners write, the AR system analyses whether intermediate steps are completed correctly, allowing feedback to focus on process rather than outcome alone. Compared to screen-based interaction, AR enables the capture of richer data, including pauses, revisions, and hesitation patterns, offering deeper insight into learning processes.

Teachers may also use AR to model worked examples or provide feedback on student work, with recordings stored in the learner's Phlow dashboard for later review. Remote tutors or assistants can "see through the learner's eyes" to provide live guidance, supporting hybrid and distributed learning models.

While Learn-AR remains in a conceptual and prototyping phase, its potential extends beyond immediate instructional support. The high-resolution process data captured during handwritten problem-solving offers opportunities for research into how learners develop understanding over time. By analysing not only what students write, but how they write, pause, revise, and explain, Phlow aims to contribute to a more nuanced understanding of learning trajectories and to inform future assessment design.

## 4. Discussion: ICT as a Catalyst for Assessment Reform

The dominant assessment model in Irish secondary education continues to rely heavily on high-stakes, summative examinations, most notably the Junior Cycle and Leaving Certificate. These assessments occur at fixed points in time and are primarily designed to evaluate outcomes rather than learning processes [16]. While such examinations provide standardised benchmarks and facilitate system-wide comparability, they offer only a limited snapshot of student performance. As a result, they often fail to capture how understanding develops over time, how misconceptions are resolved, or how learners respond to challenge—particularly for students whose learning trajectories are non-linear or who experience anxiety under exam conditions [17].

This reliance on episodic, outcome-focused assessment has broader implications for equity and inclusion. Students who require iterative feedback, additional time to consolidate understanding, or alternative representations of knowledge may be disadvantaged by systems that prioritise performance on a single occasion. Moreover, traditional assessment structures provide limited opportunities for learners to engage with feedback in ways that meaningfully influence subsequent learning. In many cases, feedback arrives after progression decisions have already been made, reducing its instructional value.

Phlow Academy proposes an alternative paradigm in which ICT is used not merely to digitise existing assessment practices, but to fundamentally reposition assessment as a formative, continuous, and integrated component of learning. Rather than separating instruction and evaluation, Phlow embeds assessment into every learner interaction. Each response—whether correct, incorrect, or incomplete—generates diagnostic information that informs immediate feedback and future task selection. This approach reflects extensive research demonstrating that timely, actionable feedback can significantly improve motivation, engagement, and conceptual understanding when compared to delayed or one-off assessment events [18].

In this model, assessment is reframed from a mechanism of judgement to one of diagnosis and guidance. Learners are not simply informed that an answer is wrong; instead, the system responds by identifying likely sources of difficulty and offering targeted support. Such low-stakes feedback environments encourage persistence and experimentation, reducing the fear of failure that often accompanies high-stakes testing. Over time, this supports the development of self-regulated learning behaviours, as students learn to interpret feedback, adjust strategies, and monitor their own progress.

Through its use of data analytics, Phlow aligns closely with what Clarke [19] describes as "assessment for learning," wherein evidence gathered during learning activities is used to shape subsequent instruction and support. In Phlow, every learner action contributes to an evolving mastery profile that reflects procedural fluency, conceptual stability, and emerging understanding. Feedback is delivered through a combination of visual cues, hints, scaffolds, and adaptive task sequencing, all designed to maintain momentum while addressing misconceptions.

This continuous evidence model promotes student agency by allowing learners to progress at a pace aligned with their readiness rather than their age or cohort. Learners may revisit material, repeat Phlows, or advance rapidly depending on demonstrated understanding. Such flexibility is particularly important in heterogeneous classrooms, where students often vary widely in prior knowledge, confidence, and learning speed. Research suggests that systems which allow for individual pacing and repeated engagement with content are more likely to support equitable outcomes [20].

Phlow's integration of levelled difficulty and adaptive progression also challenges the traditional one-size-fits-all logic of classroom instruction. By decoupling progression from time-based structures, the platform supports differentiation and, implicitly, forms of ungrading that focus on growth and mastery rather than ranking. In this environment, students are less likely to be labelled by early performance and more likely to experience learning as a process of continuous improvement. This creates conditions conducive to the "flow state" described by Csikszentmihalyi [4], where challenge and skill are optimally balanced, and learners remain deeply engaged without becoming overwhelmed or disengaged.

A further contribution of the Phlow model lies in its emphasis on process-based assessment,

particularly through emerging modalities such as Learn-AR. Traditional assessments typically capture only final answers, obscuring the reasoning pathways that led to those outcomes. By contrast, Phlow's data architecture—especially when extended into pen-and-paper contexts via AR—enables the capture of procedural steps, revisions, pauses, and verbal explanations. This richer evidence base allows assessment to focus not only on correctness, but on how understanding is constructed and stabilised over time.

Such process-oriented assessment aligns with longstanding critiques of outcome-only measurement, which argue that meaningful learning cannot be inferred solely from final products. By capturing learning as it unfolds, ICT-enabled systems like Phlow offer opportunities to identify misconceptions earlier, personalise support more precisely, and make assessment more instructionally useful. Importantly, this does not imply continuous grading or surveillance. Instead, process data is used formatively to guide learning, with summative judgements remaining the responsibility of educators and formal assessment bodies.

The multimodal nature of Phlow further extends the scope of assessment reform. In addition to screen-based interaction, the platform incorporates audio-only learning and voice-based reflection, enabling learners to articulate reasoning and engage with concepts verbally. These modalities provide alternative avenues for demonstrating understanding, supporting learners who may struggle with written expression or who benefit from verbal processing. When combined with adaptive analytics, multimodal evidence strengthens the validity of formative assessment by capturing a broader range of learner behaviours.

Within the Irish policy context, the Phlow model aligns strongly with the objectives of the Digital Strategy for Schools to 2027, which emphasises learner-centred pedagogy, formative assessment, and the strategic use of data to enhance teaching and learning [21]. It also responds to ongoing discussions within the National Council for Curriculum and Assessment (NCCA) regarding the need for more flexible, personalised pathways through secondary education. By providing a scalable infrastructure for continuous assessment, Phlow offers a practical illustration of how these policy ambitions might be realised in practice.

At the same time, it is important to acknowledge that platforms such as Phlow are not positioned as replacements for summative assessment. High-stakes examinations continue to serve important functions in certification, selection, and system accountability. However, by embedding robust formative assessment throughout the learning process, ICT systems can reduce the disproportionate weight placed on single exam performances. In such a model, summative assessments function as validation points within a broader evidence framework rather than as the sole arbiters of success.

The implications of this shift are significant. A move toward continuous, process-informed assessment has the potential to improve educational inclusion, support diverse learner pathways, and better prepare students for future environments that demand adaptability, initiative, and lifelong learning. If implemented thoughtfully and ethically, ICT-enabled assessment reform could help reposition education away from sorting and selection toward sustained learning and capability development.

In this sense, Phlow Academy illustrates how ICT can act as a catalyst for assessment reform—not by automating existing practices, but by enabling fundamentally different ways of understanding, supporting, and evidencing learning.

## 5. Conclusion

This paper has presented Phlow Academy as a working example of how information and communication technology (ICT) can be leveraged to reimagine assessment, progression, and learner support in secondary education. In contrast to traditional systems that prioritise time-based advancement and high-stakes terminal examinations, Phlow integrates formative assessment, adaptive feedback, and continuous evidence of learning into a coherent, learner-centred framework. In doing so, it responds directly to long-standing critiques of exam-centric schooling while aligning with international calls for more equitable, personalised, and evidence-informed educational pathways [22].

At the core of the Phlow model is a deliberate shift in how learning and assessment are conceptualised. Rather than treating assessment as a separate evaluative event, Phlow embeds it within the learning process itself. Every learner interaction contributes diagnostic information that informs feedback, scaffolding, and progression decisions. This approach reflects a growing body of research demonstrating that learning is most effectively supported when feedback is timely, contextual, and closely coupled to action [6]. By making assessment continuous and formative, Phlow seeks to transform it from a mechanism of judgement into a tool for guidance and growth.

The platform's design is explicitly grounded in established psychological and pedagogical theories, including Flow Theory [4], Mastery Learning [5], and formative assessment [6]. These theories are not referenced abstractly, but are operationalised through technical design choices such as micro-progressions, adaptive difficulty, and probabilistic mastery indicators. By embedding theory into infrastructure, Phlow demonstrates how ICT can be used to create conditions that support intrinsic motivation,

cognitive challenge, and self-regulated learning—factors that are central to long-term academic development and learner resilience [7].

A key contribution of the Phlow model lies in its emphasis on process-based assessment. Traditional assessment systems tend to privilege final answers, often obscuring the reasoning pathways, revisions, and metacognitive decisions that underpin learning. Phlow's data-driven architecture, particularly when extended through modalities such as Learn-AR, enables the capture of richer evidence about how learners arrive at solutions. This process-oriented perspective supports earlier diagnosis of misconceptions, more targeted intervention, and a more nuanced understanding of learner progress. Importantly, this evidence is used formatively rather than punitively, preserving learner agency and avoiding the risks associated with continuous grading or surveillance.

The multimodal nature of Phlow further extends its contribution to assessment reform. By supporting learning through mobile interaction, audio-only engagement, voice-based reflection, and augmented reality, the platform acknowledges that understanding can be expressed and developed in multiple ways. This inclusivity is particularly significant in secondary education, where learners vary widely in confidence, prior knowledge, and preferred modes of engagement. When combined with adaptive analytics, multimodal evidence strengthens the validity of formative assessment by capturing learning across contexts rather than confining it to formal testing situations.

Phlow also challenges the structural assumptions underpinning traditional progression models. By decoupling advancement from fixed timelines and age-based cohorts, the platform supports mastery-based progression that is responsive to individual readiness. This flexibility has important implications for equity, as it reduces the likelihood that learners will be permanently labelled by early performance or constrained by pacing decisions that do not reflect their needs. In this respect, Phlow aligns with broader movements toward ungrading, differentiation, and learner-centred pedagogy, while offering a scalable digital infrastructure through which such approaches can be implemented.

Within the Irish context, the platform responds directly to national policy priorities articulated in the Digital Strategy for Schools to 2027 [21] and to ongoing discussions led by the National Council for Curriculum and Assessment regarding the future of assessment and progression. By providing curriculum-aligned content with embedded formative assessment, Phlow offers a practical testbed for exploring how policy ambitions might be translated into classroom practice. While the platform is currently focused on Junior Cycle Mathematics, its underlying architecture is designed to be subject-agnostic and adaptable to other curricular areas.

It is important to emphasise that Phlow does not position ICT as a replacement for teachers or for summative assessment. Rather, it reframes their roles within a broader ecosystem of evidence and support. Teachers retain professional judgement and pedagogical authority, supported by richer diagnostic information and more flexible progression pathways. Summative assessments continue to serve functions related to certification and system accountability, but their dominance is reduced as formative evidence accumulates throughout the learning journey.

Looking ahead, platforms such as Phlow have the potential to inform the development of alternative credentials, modular certification systems, and hybrid assessment models that better reflect how learning unfolds over time. However, realising this potential will require careful attention to policy alignment, ethical governance, data privacy, and institutional trust. Empirical evaluation, longitudinal research, and collaboration with educators and policymakers will be essential to assess impact and ensure responsible implementation.

In its current form, Phlow Academy represents a concrete example of how ICT can shift the educational centre of gravity—from testing toward learning, from episodic measurement toward continuous evidence, and from sorting learners toward supporting them. While not a complete solution to the complex challenges facing secondary education, it illustrates how theory-led, human-centred digital design can contribute meaningfully to assessment reform. As education systems confront accelerating social and technological change, such models offer a valuable starting point for rethinking how learning is supported, evidenced, and valued.

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