Toward Inclusive Digital Drawing in Education: Comparing Direct and Indirect Visual Feedback Across Input Devices

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Abstract

Digital drawing and diagramming appear in many learning activities, yet producing a visual response depends partly on the input device. That dependence matters in education because a poorly matched interface can add motor and attentional burden before the learner reaches the disciplinary task. This paper reports a within-subject study comparing four devices under the same continuous circle-drawing task: pen display and touch screen, which provide direct visual feedback, and pen tablet and mouse, which provide indirect visual feedback. Ten participants completed 2,400 circle-drawing trials. We analyzed participant-level device means to compare accuracy, speed, and comfort across devices, and we summarized within-participant accuracy variability descriptively. The analyses showed reliable device effects for accuracy, speed, and comfort. Descriptively, direct-feedback devices showed higher mean accuracy (87.3% vs. 83.7%), faster performance (1.40 s vs. 1.93 s per circle), higher comfort (4.45 vs. 2.80 on a 5-point scale), and lower within-participant variability than indirect-feedback devices. Pen display produced the highest mean accuracy (87.5%), whereas touch screen was fastest (1.33 s per circle) and remained highly comfortable. This paper contributes foundational HCI evidence for treating input device as a learner-context variable in future device-aware educational systems. The findings suggest that direct visual feedback may reduce avoidable interaction burden in this task and that digital learning environments should account for input hardware when asking students to sketch, annotate, or diagram.

Keywords

Digital drawing, Device-aware adaptation, Direct visual feedback, Indirect visual feedback, Pen and touch input, Inclusive learning interfaces

1. Introduction

Drawing and diagramming are part of everyday learning in science, engineering, and mathematics. Learners sketch processes, annotate slides, trace shapes, and externalize ideas that are difficult to hold in words alone. Research on learner-generated drawing suggests that these activities can support understanding, but their benefits depend on task design, guidance, and the conditions under which drawing takes place [1, 2, 3, 4]. This point matters for digital education because the learner is not only working with content. The learner is also working through an interface.

In human-computer interaction, input devices differ in how tightly movement is coupled to visual output. Direct visual feedback places the display at the point of action, as with a pen display or touch screen. Indirect visual feedback separates hand movement from the display, as with a pen tablet or mouse. Earlier studies showed that direct input often improves performance in selection and crossing tasks, whereas indirect input introduces an additional spatial translation between action and display [5, 6, 7, 8]. Related work on trajectory-based interaction also shows that device characteristics matter in continuous movement, not only in discrete pointing [9].

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This distinction has practical relevance for education. Pen-enabled lecture systems and digital ink tools are already used in classrooms, especially in technical subjects where incremental annotation and diagramming are common [10]. Adaptive educational systems have traditionally concentrated on learner knowledge, goals, preferences, and navigation patterns, with less attention to the motor demands imposed by input hardware [11, 12]. Learners may therefore enter drawing-based activities with different input devices, and the system may interpret the resulting performance as evidence of task competence even when the interaction setup has shaped part of that performance. A focused question follows: when a learner is asked to sketch or diagram, does the directness of the device make the basic act of drawing easier or harder?

This paper addresses that question through a controlled drawing study. We compared four input devices, pen display, touch screen, pen tablet, and mouse, using the same continuous circle-drawing task. Ten participants completed 60 trials per device, yielding 2,400 analyzed trials. We ask whether direct visual feedback is associated with better drawing performance and user experience than indirect visual feedback in a simple task that captures foundational aspects of digital sketching. The paper contributes a precursor to device-aware adaptation: by isolating feedback directness, it identifies input device as a measurable learner-context variable that future educational systems may need to model when drawing, annotation, or diagramming forms part of the learning task.

2. Related Work

Research on input devices has long shown that device form and control-display relationships shape interaction performance. Classic pointing studies established that different devices produce different speed and accuracy profiles even in simple target acquisition tasks [5]. Work on constrained trajectories extended that argument to continuous movement, showing that tracing and steering are useful evaluation tasks in their own right because they capture movement patterns that differ from point-and-click interaction [9]. Direct versus indirect input adds another layer to this discussion. Forlines et al. [8] reported benefits for direct touch compared with mouse input in tabletop interaction, and Forlines and Balakrishnan [6] found performance advantages for direct stylus input in crossing-selection tasks. Cockburn et al. [7] further showed that device effects vary by activity, with finger input often fast but sometimes less precise than stylus input because of occlusion and control differences.

A second strand of work concerns drawing as a learning activity. Learner-generated drawing has been described as a generative strategy because it can prompt selection, organization, and integration of information [1, 2]. Later reviews refined this picture by showing that drawing does not help under all conditions. Its value depends on guidance, task demands, and the amount of effort required to produce the representation [3, 4]. For educational technology, the mechanics of producing a drawing are therefore part of the learning setup. When the interface is cumbersome, some of the learner's effort may be diverted from explanation to control.

A third strand concerns digital ink and pen-based classroom systems. Tablet-supported presentation tools have been used to support incremental annotation, slide markup, and instructor flexibility in technical courses [10]. These systems show that pen- and touch-based interaction already has a place in teaching practice. The educational literature, however, does not often isolate the effect of device directness itself, and the adaptive learning literature has paid more attention to content adaptation than to hardware-related interaction demands [11, 12]. Our study sits between these lines of work. It examines whether directness is a measurable property of the interaction setup that may matter for digital drawing tasks relevant to learning.

We therefore position the study as foundational evidence for device-aware adaptation. In this framing, device type is not merely an apparatus detail. It is an observable part of the learner's interaction context. If input hardware changes speed, accuracy, comfort, or consistency under the same task and scoring environment, future user-aware systems may need to account for that context before interpreting drawing performance as evidence of understanding, effort, or skill.

3. Method

3.1. Study Design

We used a within-subjects design in which every participant completed all four device conditions. The principal independent variable was device type. For descriptive interpretation, we also grouped devices by feedback type, direct or indirect. Condition order was counterbalanced with a balanced Latin square to reduce sequence effects. The final dataset contained 10 participants × 4 devices × 60 trials, yielding 2,400 analyzed trials.

3.2. Participants and Apparatus

Ten participants were recruited from the university student population. Participants were between 18 and 30 years of age and reported normal or corrected-to-normal vision. Before the study began, each participant completed a short questionnaire covering demographic information and prior experience with drawing tasks and input devices. Participation was voluntary.

The task was administered through the browser-based application Neal.fun Perfect Circle. The application asks the user to draw a circle around a fixed center point and returns a percentage score indicating how closely the trace matches a mathematically perfect circle. The interface also provides real-time color feedback as the trace deviates from the ideal path. We treated the application score as a task-specific performance indicator for comparing devices under the same scoring environment, not as a validated psychometric measure of drawing ability.

We compared four input devices. The pen display condition used an Apple iPad Air with a second-generation Apple Pencil, allowing participants to draw directly on the display surface with a stylus. The touch screen condition used the same iPad, but participants drew with a finger. The pen tablet condition used a Wacom Intuos graphics tablet connected to a laptop, so participants drew on a tablet surface while monitoring a separate screen. The mouse condition used a Logitech G703 connected to the same laptop, requiring participants to draw with the cursor while watching the screen. The apparatus is shown in Figure 1.

3.3. Task and Procedure

We selected a repeated circle-drawing task to compare devices through a controlled form of continuous tracing while limiting the additional variability of open-ended artistic content. Continuous circling has also been used in prior work on motor control and drawing behavior, which makes it a reasonable low-level proxy for foundational drawing performance [9, 13].

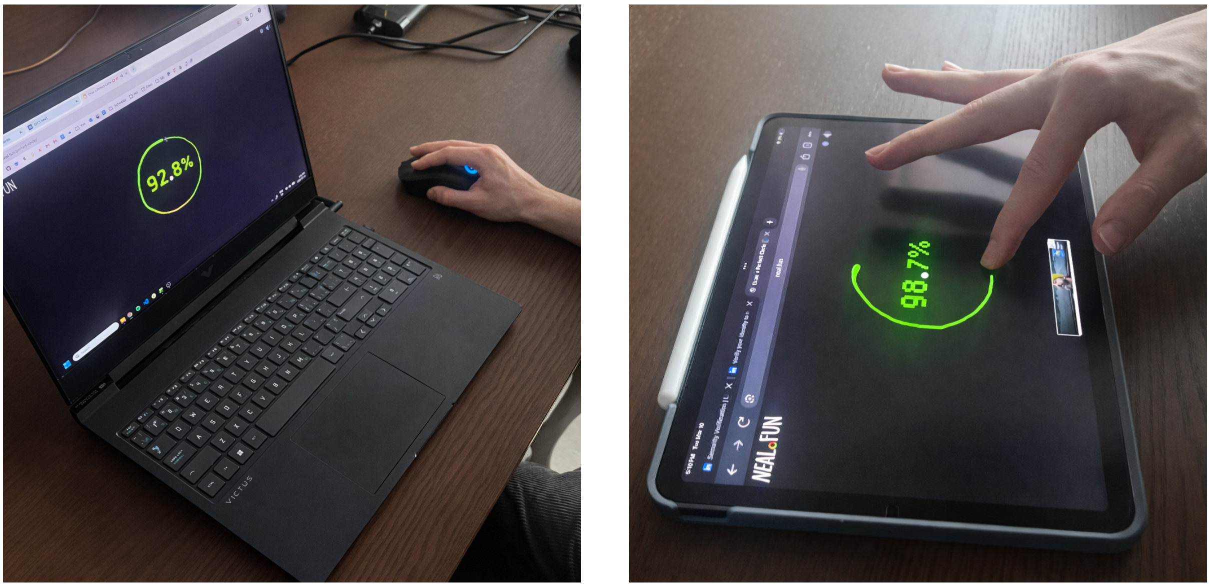
Each participant completed the study individually in a controlled setting. Participants first received instructions and short practice time with each device to reduce novelty effects. Practice trials were excluded from analysis. For each device, participants completed three blocks of 20 trials, for a total of 60 circles per device and 240 circles per participant. Short breaks were provided between blocks to reduce fatigue. After each device condition, participants rated comfort on a 5-point Likert scale. At the end of the session, participants ranked the devices and provided brief comments on ease of control and perceived difficulty. Each session lasted approximately 45 to 60 minutes.

3.4. Measures and Analysis

The dependent variables were accuracy, measured as the percentage score returned by the drawing application; speed, measured as seconds per circle (SPC); comfort, measured on a 5-point Likert scale; and consistency, measured as the standard deviation of each participant's accuracy scores within each device condition. To preserve the participant as the unit of analysis, we averaged accuracy and SPC within each participant-device condition before running repeated-measures analyses. Comfort was already recorded once per participant-device condition. We report repeated-measures analyses across the four devices for accuracy, speed, and comfort, with partial eta squared (η_p^2) calculated from the

(a) Pen display

(b) Pen tablet



(c) Mouse

(d) Touch screen

Figure 1: Input devices used in the study. Pen display and touch screen provided direct visual feedback. Pen tablet and mouse provided indirect visual feedback.

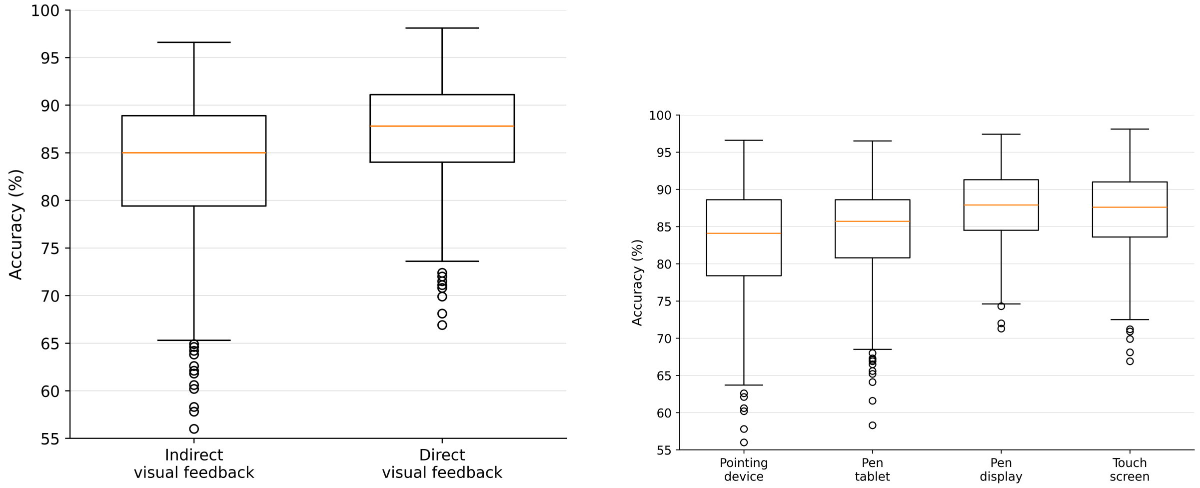
reported *F* statistics and degrees of freedom. We summarized consistency at the aggregated participant-device level and therefore report it descriptively. Direct- versus indirect-feedback summaries and device-level rankings are also descriptive because the inferential tests were conducted at the four-device omnibus level, not as post-hoc pairwise contrasts.

4. Results

Table 1 summarizes the main device-level outcomes. At the descriptive level, direct-feedback devices showed higher accuracy, lower seconds per circle, higher comfort, and lower accuracy variability than indirect-feedback devices. The pattern appeared across objective performance, subjective comfort, and within-participant variability.

Table 1
Summary of device-level outcomes. Lower values are better for SPC and accuracy SD. Accuracy SD is the mean within-participant standard deviation of accuracy scores within each device condition.

Device	Feedback	Accuracy (%)	SPC (s)	Comfort	Accuracy SD
Mouse	Indirect	83.1	2.07	2.6	6.35
Pen tablet	Indirect	84.4	1.78	3.0	6.80
Pen display	Direct	87.5	1.47	4.5	4.30
Touch screen	Direct	87.0	1.33	4.4	5.24



(a) Direct vs. indirect visual feedback

(b) Across the four devices

Figure 2: Accuracy distributions. The direct-feedback conditions show a higher center and fewer low-end failures than the indirect-feedback conditions.

4.1. Accuracy

A repeated-measures comparison across the four devices showed a reliable effect of device on accuracy, $F(3, 27) = 6.89$, $p = .001$, $\eta_p^2 = .43$. When the devices were grouped descriptively by feedback type, direct-feedback conditions averaged 87.3% accuracy, whereas indirect-feedback conditions averaged 83.7%. Figure 2a shows that the direct-feedback distribution was centered higher and had a shorter lower tail. No direct-feedback trial fell below 66.9%, whereas the indirect conditions produced multiple low-end outliers below 70%.

At the device level, pen display yielded the highest mean accuracy at 87.5%, closely followed by touch screen at 87.0%. Pen tablet averaged 84.4%, and mouse averaged 83.1%. Figure 2b shows that pen display also had the tightest central spread among the four devices. Touch screen reached the highest single-trial value at 98.1%, but its distribution was slightly wider, a pattern that is consistent with prior work showing that finger input can be fast but less precise than stylus input in some touch-selection tasks [7].

4.2. Speed

Speed followed a similar pattern. A repeated-measures comparison across devices yielded a reliable effect, $F(3, 27) = 7.33$, $p = .001$, $\eta_p^2 = .45$. Grouped descriptively by feedback type, direct devices averaged 1.40 seconds per circle, whereas indirect devices averaged 1.93 seconds per circle.

Touch screen was the fastest device at 1.33 seconds per circle, followed by pen display at 1.47 seconds. Pen tablet averaged 1.78 seconds, and mouse was slowest at 2.07 seconds. This ranking suggests that participants worked more efficiently when the trace appeared where the hand was acting. Indirect devices required participants to monitor a separate display and continuously adjust movement through a displaced control space. We did not measure cognitive load directly, so the study cannot establish that mechanism on its own. The performance pattern is nevertheless consistent with prior direct-versus-indirect input findings in HCI [8, 6, 7].

4.3. Comfort and Consistency

Comfort ratings also differed across devices, $F(3, 27) = 11.66$, $p < .001$, $\eta_p^2 = .56$. Pen display received the highest mean comfort rating at 4.5 out of 5, followed closely by touch screen at 4.4. Pen tablet was rated 3.0, and mouse was rated 2.6. When grouped by feedback type, direct devices averaged 4.45, whereas indirect devices averaged 2.80. The subjective ratings aligned with the performance results.

Consistency, measured as the within-condition standard deviation of accuracy, followed the same overall pattern. Pen display had the lowest mean standard deviation at 4.30, followed by touch screen at 5.24. Mouse and pen tablet were more variable at 6.35 and 6.80, respectively. These values suggest that the direct devices supported not only better average performance, but also more stable performance from trial to trial.

5. Discussion

The results suggest that direct visual feedback mattered in this controlled drawing task. The direct devices showed higher accuracy, faster completion, higher comfort, and lower variability than the indirect devices. This pattern is consistent with earlier work showing that performance often improves when action and display are spatially aligned [8, 6]. Its value here lies in the convergence across several outcome measures: the advantage did not appear only in speed or only in preference, but across the broader interaction profile.

The educational relevance is practical and interactional. Drawing can support explanation and understanding, yet it also takes time and effort, and its benefits depend on how the activity is structured [1, 3, 4]. This study does not estimate learning gains. It identifies a plausible source of avoidable interaction burden within a drawing task. If a learner must spend more effort controlling the line, some of that effort may be diverted from representing the idea itself. In that sense, device choice is not a neutral implementation detail for digital sketching or diagramming tasks.

One result deserves particular attention. Pen display was the most accurate device overall, but touch screen was the fastest and remained close to pen display on accuracy and comfort. That pattern matters for practice because touch tablets are more common than dedicated pen displays in many settings. Cockburn et al. [7] found that finger input can be less precise than stylus input in some target-selection tasks, and the present data do not contradict that general point. For the task studied here, direct finger input remained highly competitive. For routine educational activities such as annotating, rough sketching, or tracing, mainstream touch devices may offer a practical compromise between performance and availability.

5.1. Implications for Device-Aware Adaptation and Equity

The findings have implications for adaptive educational systems. Adaptive systems have often modeled learner knowledge, preferences, goals, or navigation paths, but input hardware can also shape the learner's interaction with a task [11, 12]. A drawing interface that detects indirect input could enlarge the drawing area, increase stroke smoothing, relax precision thresholds, or offer lightweight shape correction and tracing aids. Direct pen or touch input may need less of this support.

This perspective also calibrates the equity claim. The study does not show that one device improves learning outcomes or advances SDG 4 on its own. It shows that learners using different devices may face different interaction burdens under the same drawing task. In educational settings where device access varies, device-aware support could help avoid penalizing learners whose available hardware makes sketching slower, less comfortable, or less consistent. This paper identifies device directness as a measurable part of learner context that future educational tools can model and test in authentic learning tasks.

6. Limitations

Several limitations should shape the interpretation of the findings. The sample was small and drawn from a relatively homogeneous university population. Prior experience with the devices was collected but not analyzed in a way that would support subgroup comparisons. The task was intentionally simple, which helped isolate basic control differences but does not capture the full complexity of authentic diagram construction, note-taking, collaboration, or problem solving. The application score was treated as a consistent task-specific metric for this task, without extending it to a broader measure of drawing skill. The inferential tests evaluated overall device effects, so the device-level rankings should be read as descriptive patterns unless confirmed with pairwise analyses in a larger dataset. The study did not measure learning outcomes, mental workload, or long-term fatigue, and comfort was captured through a single post-condition rating. The results should therefore be read as evidence about foundational drawing performance and user experience in this setting, not as a direct estimate of educational gain.

7. Conclusion

This paper compared four input devices in a controlled drawing task relevant to digital learning interfaces. Direct visual feedback devices showed higher accuracy, faster performance, higher comfort, and lower accuracy variability than indirect devices in this setting. Pen display achieved the highest mean accuracy, whereas touch screen was the fastest device and remained competitive across the measured outcomes. The findings suggest that directness may matter not only for low-level HCI performance, but also for the design of learning environments that ask students to sketch, annotate, or diagram. The paper contributes foundational evidence for treating input device as a learner-context variable in future user-aware drawing systems. Although the study does not test learning outcomes directly, it points to a practical design concern with educational relevance. When digital drawing is required, the interface should not add unnecessary motor and attentional burden or interpret device-induced difficulty as learner difficulty. This concern is relevant to SDG 4 on quality education, particularly in higher-education settings where digital annotation and diagramming are routine parts of learning [14]. Future work can test whether device-aware support improves authentic educational tasks and whether these effects vary across learner groups, subject domains, and levels of drawing guidance.

Declaration on Generative AI

During manuscript preparation, OpenAI ChatGPT was used to assist with language editing and formatting. The authors reviewed and revised the manuscript, made all decisions regarding the study design, analysis, and interpretation, and take full responsibility for the final paper.

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