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Interest-Oriented Teaching Reform of Signals and Systems through Contextual Tasks and AI-Assisted Verification

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Abstract: *Signals and Systems requires students to connect abstract mathematical representations with observable phenomena and independently apply analytical methods. This paper proposes an interest-oriented teaching framework integrating contextual introductions, prediction and verification, short after-class exercises, and artificial intelligence-assisted reasoning. Echo generation, harmonic composition, and sampling ambiguity provide concrete entry points to convolution, Fourier analysis, and sampling. Each activity moves from an initial prediction to mathematical analysis, verification, and explanation under changed conditions. Brief, differentiated exercises are distributed across lessons to support retrieval and make progress visible. AI is used to provide hints, alternative explanations, and counterexamples after students formulate their own judgments; its suggestions must be checked against definitions, calculations, or simulations. The framework offers a compact, testable approach to making learning more approachable while preserving conceptual rigor and independent reasoning.*

Keywords: *signals and systems, learning interest, contextual teaching, retrieval practice, artificial intelligence*

1. Introduction

Signals and Systems connects mathematical foundations with communication, control, and signal processing. Its central topics require students to move among equations, waveforms, system properties, and engineering interpretations. A learner may reproduce a convolution calculation yet struggle to explain why the operation represents a system response. Similarly, remembering a sampling condition does not necessarily mean recognizing when distinct continuous-time signals generate identical samples.

An instructional challenge is therefore to make the purpose of analysis visible before students encounter extensive symbolic manipulation. An interesting demonstration alone is insufficient: students also need opportunities to formulate predictions, test explanations, and independently use the resulting knowledge. The intended improvement is a more approachable learning process with clearer evidence of understanding. Mathematical reasoning remains essential.

Interest-development research distinguishes the triggering and maintenance of situational interest from the development of more enduring individual interest [1]. This distinction informs the present design: a familiar phenomenon initiates attention, while an unresolved question and achievable analytical progress sustain engagement. The paper proposes a framework for selected course units and an evaluation protocol for subsequent implementation. It reports a pedagogical design rather than an evaluated classroom intervention.

2. Research hypotheses

Three hypotheses organize future evaluation. 1) contextual introductions explicitly connected to the lesson objective will support sustained engagement with the analytical problem. 2) brief exercises combining feedback with distributed retrieval will support conceptual understanding and delayed retention. 3) asking students to verify AI explanations after independent reasoning will support error detection and transfer without AI assistance.

The design draws on complementary educational principles. Research on learning techniques supports practice testing and distributed practice [2]. Constructive alignment connects intended learning

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outcomes, teaching activities, and assessment [3]. Active-learning research provides a broader rationale for student participation in reasoning tasks [4]. These findings motivate the proposed activities; they do not establish their effectiveness in this particular course.

AI introduces both opportunities and reliability concerns in education [5]. Accordingly, a fluent explanation is treated as a claim requiring examination. The framework combines accessible entry points with accountable reasoning: students predict, calculate, verify, explain, and then reconsider the problem under changed conditions. Interest is expected to develop through meaningful participation and visible progress.

3. Research design

3.1. Scope and instructional sequence

The proposal targets undergraduate Signals and Systems teaching, with an initial pilot in convolution, Fourier analysis, and sampling. They can be implemented with teacher-prepared plots, short audio demonstrations, and a familiar computing environment. Each activity follows five steps: encounter a phenomenon, predict a result, construct and use a mathematical model, verify the result, and explain what changes when an assumption or parameter changes. The teacher states the learning objective and returns to the original question at the end. The same sequence makes expectations predictable across units and gives students a structure for independent analysis.

Figure 1 illustrates the teaching method. A contextual introduction leads to a focused question and an independent prediction. Students then construct a model and analyze the problem with teacher guidance, using AI hints or counterexamples only after an initial attempt. Calculations, simulations and classroom discussion support verification. Short after-class tasks provide retrieval and transfer opportunities, while feedback directs correction and targeted review.

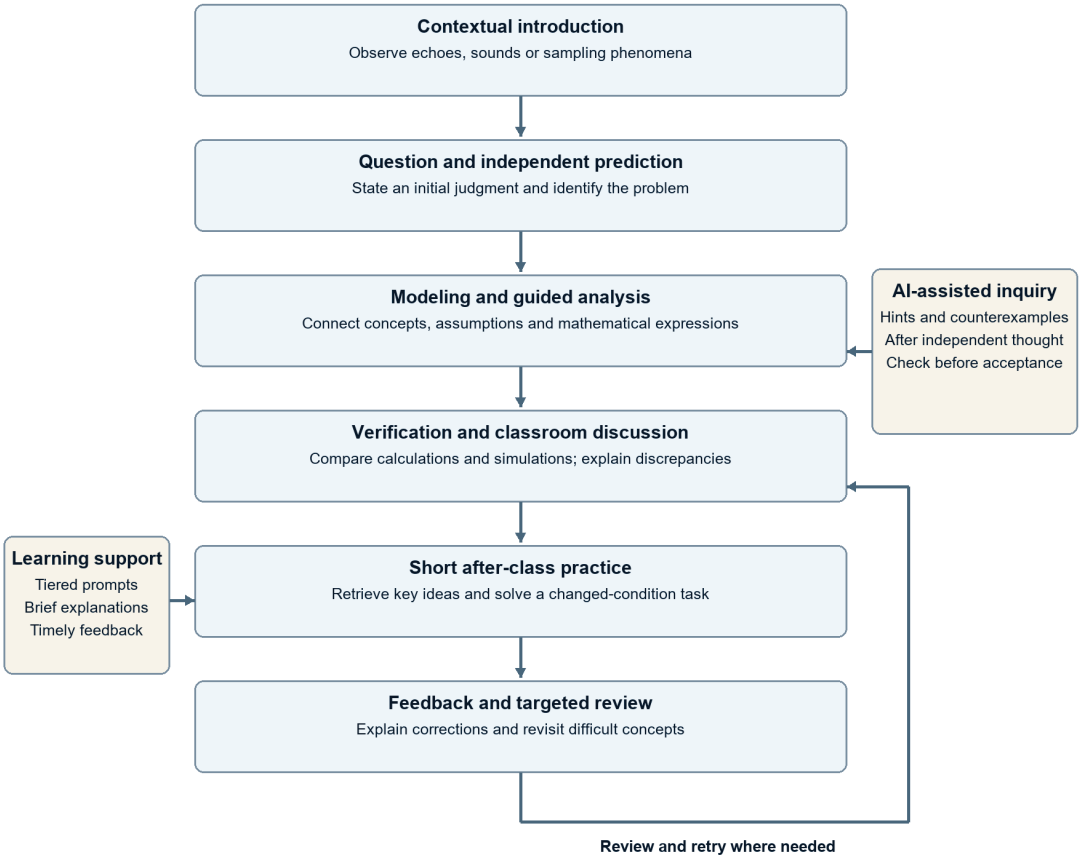

Figure 1. Interest-oriented teaching process for Signals and Systems

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3.2. Contextual introductions and prediction

A contextual introduction is designed to occupy approximately 3-5 minutes. It presents one phenomenon, asks one focused question, and requests a short prediction. The context should be easy to perceive, admit an appropriate simplified model, and connect directly with the lesson objective. Table 1 gives proposed examples rather than completed teaching activities.

Table 1. Proposed contextual introductions and short tasks

Topic	Introduction and prediction	Short learning task
Time transformations	Delayed or faster audio playback: what changes?	Distinguish a time shift from time scaling using a marked feature
Convolution	A direct sound and one echo: when will responses overlap?	Calculate a short sequence response and explain overlap
Fourier analysis	Synthetic sounds with the same fundamental but different harmonics	Locate the expected spectral components and explain differences
Sampling	Two continuous-time sinusoids producing identical samples	Check sample values and identify the missing reconstruction conditions
System properties	Amplification compared with clipping	Test linearity using specific inputs and superposition

Visualizations follow student predictions. For a time transformation, students first mark the expected location of a recognizable feature. For a spectrum, they predict components from the signal expression before inspecting a plot. The teacher then asks which part of the prediction changed and why. This makes visualization a source of evidence rather than a substitute for analysis.

Interest maintenance requires an unresolved question to remain visible throughout the lesson. The introduction therefore establishes a question that students cannot yet fully explain, and each subsequent activity supplies part of the analytical method needed to answer it. The teacher records the initial predictions and revisits them after modeling and verification. This progression is intended to connect the appeal of the phenomenon with the value of the mathematical method, rather than relying on a succession of unrelated demonstrations.

For example, the echo lesson begins by asking what changes when a delayed copy is added to a sound. Students first describe what they hear, then predict how the delay and echo coefficient affect the response. Guided analysis connects those judgments to an impulse-response model and convolution. Before inspecting the computed output, students predict where contributions will overlap. At the end, they explain the original phenomenon using the model and consider a different delay. The same context thus develops from observation into a question that requires course knowledge.

To sustain participation, students can choose between equivalent short examples, such as two echo settings, while addressing the same conceptual objective. The teacher acknowledges a justified revision of an initial prediction as useful analytical progress and invites students to identify the evidence that changed their view. A closing explanation, such as why the model accounts for an observed difference, reconnects the lesson with its opening question. Whether these activities maintain interest beyond the immediate demonstration must be examined during implementation.

3.3. Short exercises and differentiated support

After-class exercises are designed to take approximately 5-10 minutes, subject to pilot workload records. Each addresses one learning objective and includes a short explanation prompt. A foundational task identifies or explains a concept; an application task requires a brief calculation or interpretation; an optional extension changes one condition. All students work toward common conceptual outcomes, while prompts and partially completed diagrams provide additional support where needed.

A typical response includes an answer and one sentence identifying the decisive condition or the reason for revising an initial judgment. Teachers use these explanations to distinguish conceptual errors from arithmetic mistakes. Feedback identifies the next action, such as checking an index range or applying a definition to a counterexample. It should not merely mark an answer as incorrect.

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Important concepts recur across lessons. Following an initial convolution exercise, students later interpret a response from an impulse response and subsequently connect time-domain convolution with frequency-domain multiplication. The exact intervals should fit the course timetable and be reviewed during the pilot. The purpose is repeated retrieval with meaningful variation, rather than additional repetitive work.

Before checking an answer, students identify the condition or relationship on which their solution depends. Feedback then addresses that element explicitly, and students make one targeted correction. This sequence is designed to make progress visible without turning a brief exercise into a lengthy reflective report.

A closing prompt asks students to complete a concrete statement such as: I can now identify which input samples contribute to a selected output sample. This statement is checked against the submitted solution and a subsequent unassisted question. Students who express confidence but cannot explain their answer receive a focused follow-up task; students who reason correctly but remain uncertain receive feedback identifying the evidence of their competence. Perceived mastery is therefore treated as a judgment to calibrate against performance.

3.4. AI-assisted explanation and verification

Students first submit an initial judgment or a specific difficulty. They may then ask AI for a hint, a contrasting explanation, or a counterexample. Finally, they check the suggestion using a definition, a calculation, or an independently understood simulation. A compact submission retains the initial judgment, the relevant suggestion, and the verification explanation. Full conversation transcripts are unnecessary unless required for a specific research question.

For example, a student may ask: “Identify the condition missing from my linearity test, but do not provide the complete solution.” Another prompt may request a counterexample to the claim that an increasing output amplitude proves linearity. For generated code, students must explain the input, output, indexing, and parameter meanings, and verify one simple case manually. Successful execution alone is not evidence of conceptual understanding.

Teacher-prepared hints and worked feedback provide an equivalent route for students without access to AI. Unassisted tasks remain necessary to determine whether the learner can apply the method independently. AI access conditions should be recorded during evaluation because unequal support could otherwise distort comparisons.

3.5. Worked example of convolution through an echo

The echo activity begins with a direct sound and a version containing one delayed replica. Students predict the response to a short pulse and then to two adjacent pulses. The model represents a simplified discrete-time system with a direct path and one echo. Let the impulse response be

$$h[n] = \delta[n] + a\delta[n - D] \tag{1}$$

where $\delta[\cdot]$ denotes the unit impulse, a is the echo coefficient, and D is a nonnegative integer delay. Convolution gives $y[n] = x[n] + ax[n - D]$. For $x[0] = 1$ and $x[1] = 2$, with all other samples zero, $a = 0.5$, and $D = 1$, students independently obtain $y[0] = 1$, $y[1] = 2.5$, and $y[2] = 1$. They then verify the result computationally and explain why the middle sample contains overlapping contributions. An extension increases D and asks students to predict the output support before recomputing it.

The model deliberately excludes repeated reflections and other acoustic effects. Stating this limitation helps students distinguish a useful model from a complete description of a room. The after-class task changes a or adds a second delayed impulse. Students explain the origin of each response component; AI may check arithmetic or code after the initial attempt.

3.6. Worked example of sampling ambiguity

The sampling activity compares $x_1(t) = cos(2\pi\ 100\ t)$ and $x_2(t) = cos(2\pi\ 900\ t)$, with

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time measured in seconds. At a sampling rate of 1000 Hz, the sampled sequences are $cos(0.2\pi n)$ and $cos(1.8\pi n)$, respectively. For integer n, these sequences are identical. Students check several values and then explain the identity algebraically.

The question is whether samples alone identify the original continuous-time signal. Students discuss the prior assumptions required for reconstruction and why a memorized sampling-rate rule needs careful interpretation at boundary cases. A changed-frequency task tests whether they can repeat the reasoning independently. The activity links the observation with a precise statement about information loss and reconstruction conditions.

4. Empirical analysis

4.1. Evidence status and evaluation outcomes

Table 2 separates the evaluation dimensions. The primary learning outcome should be performance on an unassisted transfer task. Secondary outcomes may include delayed retention, conceptual error patterns, interest, perceived mastery, and workload. Measures should be selected before examining results to reduce selective reporting.

Table 2. Proposed evaluation measures and interpretation limits

Dimension	Evidence to collect	Interpretation limit
Interest	Brief responses about problem value and willingness to continue	Novelty and visible participation may not persist
Perceived mastery	Confidence prediction before an independent task	Confidence must be compared with actual performance
Understanding and transfer	Unassisted explanations and changed-condition tasks	Familiar calculations alone provide limited evidence
Retention	A comparable task after a declared delay	Report the interval and intervening instruction
Workload	Completion time and reported sources of difficulty	Lower effort does not necessarily indicate better learning

Short interest items can ask whether students want to continue explaining the phenomenon and can identify the purpose of the method. Locally developed items require piloting for clarity and should not be described as a validated scale without supporting evidence. Confidence judgments can be compared with actual answers to examine whether students develop more accurate self-assessment.

4.2. Prospective analysis and implementation control

Before and after tasks should address comparable objectives with common scoring criteria. An analytic rubric can assess conceptual accuracy, justified use of conditions, calculation or verification, and explanation. Calibration with anonymized examples and independent scoring of a subset can help identify ambiguous criteria.

Analysis should report the eligible cohort, valid paired sample, missing observations, and assessment conditions. Where appropriate, summarize paired changes with uncertainty intervals and examine whether conceptual error patterns change. A parallel or historical comparison is informative only after considering prior preparation, teaching conditions, and task difficulty. A single-group improvement cannot isolate the reform from maturation, repeated testing, or other instruction.

The hypotheses require different evidence. 1) concerns sustained engagement across activities, rather than one favorable reaction. 2) concerns independent performance and retention. 3) requires students to detect problematic AI reasoning and complete subsequent tasks without AI. If interest increases while transfer does not, the activities may need stronger links between demonstrations and analytical practice. If workload rises substantially, task length or tool requirements should be reduced before broader implementation.

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5. Conclusion

The proposed reform connects familiar signal phenomena with prediction, mathematical modeling, verification, and independent explanation. Its course-specific contribution is to organize contextual introductions, distributed short exercises, and AI-assisted reasoning around the same analytical process. Echo and sampling examples illustrate how an accessible question can lead to rigorous treatment of system response and signal representation.

The intended benefit is a learning environment in which students can enter abstract topics more readily, recognize progress, and explain what they have learned. Such benefits remain prospective. Simplified contexts may conceal model limitations, visualizations may create unwarranted confidence, and AI may encourage premature reliance on external answers. Explicit assumptions, changed-condition tasks, and unassisted assessment are therefore integral to the design.

Future classroom implementation should examine interest and independent learning together, alongside the time required. Evidence of a more approachable experience is strongest when students also demonstrate accurate reasoning, transfer, and retention. The framework provides a focused basis for that evaluation without claiming unobserved teaching effects.

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