

Material-based contextualization in physics: Student preference for household objects versus laboratory equipment in a resonance demonstration

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Physics demonstrations are celebrated for enlivening lectures and anchoring understanding, yet remarkably little is known about how the choice of demonstration materials, namely, familiar household objects versus specialized laboratory equipment, may shape students' affective evaluations. A total of 288 secondary and college students observed two resonance demonstrations—one using wine glasses as everyday focal objects and one using tuning forks as laboratory focal objects—and completed a survey requesting an overall preference (household/lab/no preference) and Likert ratings on seven perception items for each demonstration. Demonstration order was counterbalanced across class sessions to guard against sequence effects. Overall, students far more often preferred the wine-glass demonstration (58.3%) over the tuning-fork demonstration (14.9%), with 26.7% reporting no strong preference; this preference pattern was consistent across both secondary and college students and did not differ significantly between male and female students. Preference distributions were also independent of presentation order. Paired comparisons showed that the household demonstration was rated significantly higher in interestingness, novelty, relevance to daily life, and its ability to stimulate interest in science. Importantly, clarity of the phenomenon and self-reported support for understanding resonance did not differ significantly between the two demonstrations, supporting the interpretation that the preference for the household condition is not attributable to the phenomenon being easier to observe or the concept easier to grasp. The results are theoretically grounded in cognitive load and situated cognition frameworks to explain how material-based contextualization may enhance student engagement without increasing perceived cognitive burden. These findings suggest that a seemingly simple instructional design choice, i.e., using a recognizable household object as the focal material in a physics demonstration, can meaningfully enhance student engagement and perceived relevance without sacrificing conceptual clarity.

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I. INTRODUCTION

Physics demonstrations occupy a unique position in physics education: they translate abstract principles into vivid, observable events that can energize a lecture hall and anchor subsequent discussion. Yet despite their ubiquity, the literature has seldom examined how the choice of materials—everyday household objects versus purpose-built laboratory equipment—might systematically influence students' affective responses. The present study addresses this gap by comparing students' preferences and multi-item ratings after observing the same resonance

demonstration performed with either wine glasses (household object) or tuning forks (laboratory apparatus) in counterbalanced order.

A. Role of demonstrations in conceptual change and motivation

Interactive lecture demonstrations have been shown to trigger measurable learning gains when students predict, observe, and explain outcomes [1–4]. Large-sample survey studies have found that many upper-secondary students perceive physics demonstrations as interesting, enjoyable, and useful [5–7], and Crouch *et al.* documented significant conceptual improvement when demonstrations were made interactive rather than purely passive [2]. Delivery modality can also matter: Kestin *et al.* found that high-quality physics demonstration videos incorporating visual cues, contrasting cases, and slow-motion playback supported greater student learning than live demonstrations presented using the same instructional script [8]. Together, these strands of evidence highlight demonstrations as versatile

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learning tools, but they leave untested how material choice affects learners' judgments of novelty, clarity, and perceived scientific rigor.

B. Contextualization and everyday artifacts

Constructivist theories emphasize that new knowledge is most readily built upon prior experience [9,10]. Research on context-based science education indicates that familiar, real-world contexts can improve students' attitudes or motivation while supporting conceptual understanding comparable to conventional instruction; individual interventions have also reported gains in achievement [11–13]. In the context of lecture demonstrations, this often involves a practice we define here as material-based contextualization, the deliberate use of familiar, household objects as focal demonstration materials to illustrate abstract physical principles. While this is a venerable tradition in science communication, it represents a distinct pedagogical modality from the narrative-based contextualization typically found in written exercises and word problems, and the two should not be conflated in either research or instructional design.

C. The unresolved gap

Practitioner guides have long encouraged instructors to “think outside the lab,” integrating readily available household objects such as wine glasses and compasses for classroom science instruction [14–16]. However, this literature is almost entirely qualitative or descriptive, functioning as instructional “how-to” guides based on anecdotal evidence of student interest [17–20]. Conversely, while the empirical physics education research literature provides rigorous quantitative data on lecture demonstrations, it has focused primarily on pedagogical modality—such as the benefits of interactive versus passive engagement and the effect of embedding question usage [21,22]—leaving the impact of the demonstration materials themselves largely unexamined.

Consequently, despite the long history of using household objects in physics teaching, the practice has yet to be subjected to a rigorous, data-driven comparison against specialized laboratory equipment. There is a lack of controlled studies that isolate material type as the sole manipulated variable while holding the explanatory narrative and instructional quality constant. Without such empirical evidence, it remains unknown whether students truly prefer household objects or if such materials meaningfully influence distinct affective dimensions such as interestingness, novelty, and perceived scientific rigor. This study addresses this gap by a controlled comparison of material-based contextualization in a physics demonstration setting.

D. The present study

To inform this dilemma, we measured (i) overall preference, (ii) seven affective ratings—interestingness,

novelty, clarity, conceptual support, everyday relevance, perceived scientific authenticity, and stimulation of science interest—and (iii) qualitative rationales after each participant experienced both versions of the resonance demonstration. By isolating material type as the sole manipulated variable within a controlled, counterbalanced design, this study provides empirical evidence on how an everyday focal object versus a laboratory focal object can shape student perceptions in a large-lecture physics setting, offering evidence-based practical guidance to instructors while designing or planning classroom demonstrations.

II. METHOD

A. Participants and materials

The participants were 288 students (170 female, 59.0%; 118 male, 41.0%) drawn from both secondary and higher education contexts in China, including Grade 10 high school students ($N = 96$, 33.3%), first-year undergraduate science, technology, engineering, and mathematics (STEM) majors ($N = 128$, 44.4%), third-year undergraduate physics majors ($N = 54$, 18.8%), and a small cohort of first-year graduate students ($N = 10$, 3.5%) at a major Chinese public university. The high school participants were recruited from one general public senior high school in southern China. Participants' ages ranged from 15 to 30 years ($M = 18.27$, $SD = 2.54$). Participation was voluntary, and data collection was conducted anonymously to encourage candid responses.

A core physics concept, mechanical resonance, was demonstrated using two setups:

Version A (Household Object): Two identical wine glasses were used. One glass (exciter) was struck with a small rubber hammer, causing it to vibrate at its natural frequency. A ping-pong ball placed lightly touching the rim of the second, identical glass (receiver) would be driven into oscillation and bounce off when the receiver resonated with the sound waves from the exciter, as shown in Fig. 1(a). The resonance was disrupted by adding water to the exciter glass, changing its natural frequency, after which the ping-pong ball on the receiver glass no longer bounced.

Version B (Laboratory Equipment): Two identical tuning forks with the same natural frequency were used, as shown in Fig. 1(b). One tuning fork (exciter) was struck with a rubber hammer. The resonance of the second tuning fork (receiver) was demonstrated (e.g., by bringing it close to a suspended ping-pong ball, which would then be set into motion). To disrupt resonance, a small mass (e.g., a screw or clip) was added to the exciter tuning fork, altering its natural frequency.

Both demonstrations used the same auxiliary classroom materials, including a support stand, rubber hammer, and ping-pong ball, to make the phenomenon visible. The intended contrast was between a household focal object

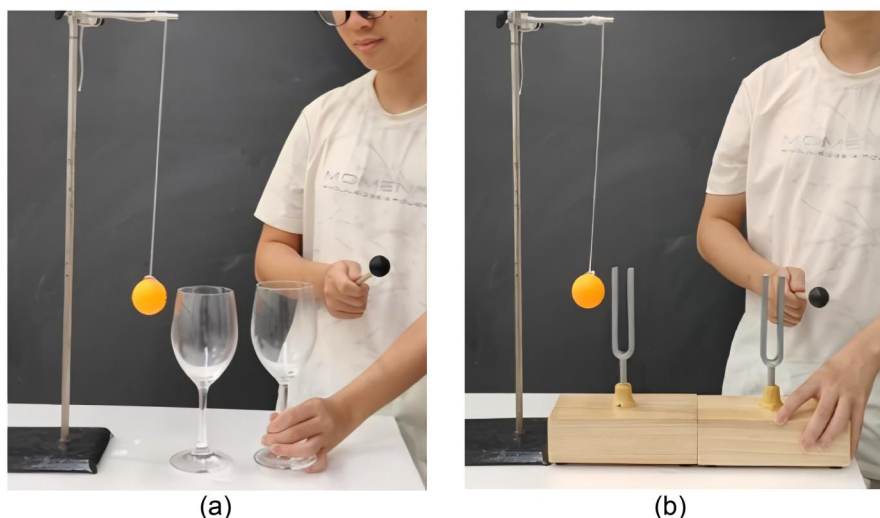


FIG. 1. Experimental setups for demonstrating mechanical resonance using (a) wine glasses and (b) tuning forks.

(wine glass) and a standard laboratory focal object (tuning fork).

These two specific setups were selected as a complementary pair to ensure conceptual equivalence and observational consistency. Specifically, they were designed to (1) illustrate the identical physics principle of mechanical resonance and (2) provide comparable clarity for observing the phenomenon. By holding the conceptual content and visual accessibility constant, the experimental design isolated the focal resonating object—wine glass versus tuning fork—as the primary variable influencing student perception.

B. Procedure

The study employed a within-subjects design with counterbalanced presentation order. Students were divided into two groups according to their class session. In the wine-glass-first group (order = 0; $N = 153$), students first observed the demonstration using wine glasses, followed by the demonstration using tuning forks. In the tuning-fork-first group (order = 1; $N = 135$), the order was reversed. For clarity in the analyses that follow, the wine-glass demonstration is referred to as the household demonstration and the tuning-fork demonstration as the lab demonstration. Both demonstrations were presented by the same instructor using the same explanatory narrative and lasted the same amount of time (approximately 5 min each). Immediately after observing both demonstrations, students completed a structured questionnaire assessing overall preference and their evaluations of each demonstration along seven items. Since students evaluated the demonstrations after observing both versions, the ratings should be interpreted as retrospective perceptions of two demonstrations experienced as a pair rather than as isolated measures of learning from each demonstration separately.

C. Questionnaire

The questionnaire (see the Appendix) comprised four parts.

Background Information: Students provided their grade level, age, and gender.

Overall Preference: Students indicated whether they preferred Demonstration A (wine glass), Demonstration B (tuning fork), or had no strong preference and provided a brief written justification for their choice.

Seven-Item Ratings: Using a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree), students rated each demonstration on seven perception items: (1) interestingness, (2) novelty, (3) clarity of the phenomenon, (4) self-reported support for understanding resonance, (5) relevance to everyday life, (6) perceived scientific authenticity (the extent to which it felt like a “science experiment”), and (7) stimulation of interest in science more broadly. These items measured students’ immediate perceptions of the demonstrations rather than objective learning outcomes.

Open-Ended Questions: Students described the perceived advantages of using household objects and laboratory equipment for science demonstrations in general and offered any additional comments or suggestions.

D. Data analysis

Data analysis proceeded in several stages to address the study’s research questions concerning overall preference patterns and multi-item perceptions of the two demonstrations.

First, descriptive statistics were calculated for all variables. Overall preference responses (household, lab, or no preference) were summarized using frequency counts and percentages. To determine whether the distribution of

preferences differed from chance, a chi-square goodness-of-fit test was conducted. Because the primary theoretical contrast concerned preference for the everyday-object demonstration over alternatives, a complementary one-tailed binomial test was also performed, treating “household preference” versus all other responses as the comparison. To examine whether presentation order influenced preference, a Pearson chi-square test of independence was conducted comparing preference distributions across the two counterbalanced groups (wine-glass-first versus tuning-fork-first).

Second, comparisons of students’ evaluations of the two demonstrations were conducted using paired-samples t tests for each of the seven rating items: interestingness, novelty, clarity of the phenomenon, self-reported support for understanding resonance, relevance to everyday life, perceived scientific authenticity, and stimulation of interest in science. Because each participant rated both demonstrations, the paired design permitted direct comparison of the two conditions while controlling for individual differences. For each paired comparison, Cohen’s (d_z) was reported as the paired-samples standardized effect size and calculated as $d_z = \frac{t}{\sqrt{N}}$.

Third, subgroup analyses were conducted to examine the generalizability of the preference pattern across school levels and gender. For categorical preference outcomes, Pearson chi-square tests of independence were used to compare preference distributions between secondary and college students and between male and female students. Cramér’s V was reported as an effect-size measure for these contingency-table analyses.

Fourth, to examine whether the household-lab rating contrast differed across groups on the seven perception items, a series of mixed (within-between) comparisons were conducted. In these analyses, demonstration type (household vs lab) was treated as a within-participant factor, while school level (secondary vs college) or gender (male vs female) served as the between-participant factor. The primary inferential quantity of interest was the demonstration $\times$ group interaction, which tests whether the magnitude or direction of the household-lab difference varies between groups. Because seven interaction tests were conducted for each grouping variable (one per rating item), p values were adjusted using the Holm sequential correction procedure to control the familywise error rate.

Finally, responses to the open-ended questions were analyzed using a consensus coding procedure. A six-code, nonmutually exclusive binary codebook was developed to capture recurring themes in students’ reasoning about the advantages of household objects and laboratory equipment. Two coders independently coded the open-ended responses from all participants. Disagreements were then resolved through discussion to produce the final consensus coding used in the results.

TABLE I. Overall preference distribution.

Preferred demonstration	Count	Percentage
Wine glass (A)	168	58.3%
Tuning fork (B)	43	14.9%
No preference	77	26.7%

III. RESULTS

A. Overall preference

Across the 288 valid questionnaires, Table I shows that 168 students (58.3%) preferred the wine-glass demonstration, 43 students (14.9%) preferred the tuning-fork demonstration, and 77 students (26.7%) reported no strong preference. A χ^2 goodness-of-fit test confirmed that the three-way distribution departs significantly from chance, $\chi^2(2, N = 288) = 87.02$, $p < 0.000001$. When no-preference responses are absorbed into the nonhousehold category, a one-tailed binomial test likewise confirms that a significant majority favor the wine-glass demonstration (168 of 288, $p = 0.0028$). The preference for the household demonstration was therefore not a marginal trend but a clear and statistically robust finding.

To examine whether presentation order influenced students’ choices, a Pearson chi-square test of independence was conducted comparing preference distributions between the wine-glass-first and tuning-fork-first groups. The result showed that the order of presentation (wine-glass first vs tuning-fork first) did not influence preference, $\chi^2(2, N = 288) = 1.48$, $p = 0.476$, indicating that order was effectively controlled in the study design.

B. Rating comparisons

Mean ratings for each of the seven evaluative items are summarized in Table II. Paired t tests reveal that the wine-glass demonstration was rated significantly higher than the tuning-fork demonstration on four items—interesting, novel, relevance to everyday life, and stimulating interest in science—whereas the tuning-fork demonstration was rated higher on perceived scientific authenticity. Notably, there were no statistically significant differences for the two clarity-related items (clear visibility of the phenomenon and helps understanding), indicating that students’ overall preference for the everyday-object demonstration cannot be attributed to it being easier to observe or perceived as more helpful for understanding. This equivalence in clarity was a deliberate design feature when constructing the two demonstrations (both were designed to be equally observable), and the results confirm that this control was successfully achieved. The largest effect was observed for relevance to everyday life; the effects for interestingness, novelty, and stimulation of science interest were smaller but statistically significant.

TABLE II. Mean ratings for the seven perception items for the household and laboratory demonstrations ($N = 288$).

Item	Wine-glass mean	Tuning-fork mean	Difference	Cohen's d (d_z)	Sig.
Interestingness	4.43	4.19	0.24	0.34	**
Novelty	4.22	3.86	0.36	0.40	**
Clarity	4.35	4.26	0.09	0.09	n.s.
Self-reported support for understanding	4.48	4.42	0.06	0.09	n.s.
Relevance to everyday life	4.43	3.59	0.84	0.79	**
Scientific authenticity	4.27	4.39	-0.12	-0.15	*
Stimulating interest in science	4.34	4.05	0.29	0.36	**

Note. Difference = wine-glass mean minus tuning-fork mean. Positive values favor the wine-glass demonstration; negative values favor the tuning-fork demonstration. * = $p < 0.05$; ** = $p < 0.001$; n.s. = not significant.

C. Open-ended responses

The open-ended responses were coded using a six-code, nonmutually exclusive binary codebook. The six codes captured: (1) everyday relevance, familiarity, and accessibility; (2) interest, novelty, fun, and curiosity; (3) clarity, observability, and support for understanding; (4) scientific rigor, professionalism, authenticity, and precision; (5) reliability, stability, safety, and durability; and (6) the view that both demonstrations were useful or complementary. Two coders independently coded the open-ended responses from the 288 participants using a six-code, nonmutually exclusive binary codebook. Because the codes were not mutually exclusive, Cohen's κ was calculated separately for each code. Inter-coder reliability was substantial to very strong, with κ ranging from 0.686 to 0.906 across the six codes (mean = 0.801, median = 0.808). Disagreements were resolved through discussion to produce the final consensus coding reported in Table III.

The qualitative pattern aligns closely with the quantitative results. Everyday relevance dominated the remarks favoring the wine-glass demonstration, with many students emphasizing that familiar objects made resonance feel “closer” and more meaningful in daily life. Responses favoring the wine-glass demonstration also emphasized familiarity, interest, and novelty. Responses favoring the

tuning-fork demonstration more often emphasized scientific authenticity, professionalism, precision, reliability, or safety. Comments on clarity were mixed: some students described the wine-glass demonstration as more vivid and intuitive, whereas others viewed the tuning-fork demonstration as more controlled or precise. This convergence strengthens the interpretation that the wine-glass demonstration was primarily valued for relevance and engagement, while the tuning-fork demonstration retained symbolic value as a more formal and scientifically authoritative apparatus—a perception that is directly reflected in the significantly higher perceived scientific authenticity score for the lab demonstration in the quantitative data.

Taken together, these written narratives align closely with the quantitative pattern: the household demonstration is more often described as engaging, novel, and personally relevant, while the lab demonstration is more often described as scientifically authoritative and reliable. The convergence between the quantitative ratings and the qualitative responses strengthens confidence in the interpretation of both data sources.

D. Secondary versus college students

This subsection examines whether (a) students' categorical preference (household vs lab vs no preference)

TABLE III. Qualitative themes and illustrative quotations ($N = 288$).

Theme	Frequency	Percentage	Illustrative student remarks
Everyday relevance, familiarity, and accessibility	230	79.9%	“Wine glasses are things we see at home, so the experiment feels closer to real life.”
Interest, novelty, fun, and curiosity	97	33.7%	“The glass version is novel and more fun.”
Clarity, observability, and support for understanding	175	60.8%	“The vibration of the glass rim is easier to see and hear.”/“The tuning fork gives a cleaner tone and shows resonance more precisely.”
Scientific rigor, professionalism, authenticity, and precision	201	69.8%	“A tuning fork looks more professional.”/“Laboratory equipment feels more like a real scientific experiment”
Reliability, stability, safety, and durability	25	8.7%	“Tuning forks feel sturdier and safer for class use.”
Comparable value or complementary use	55	19.1%	“Both demonstrations are useful.”/“The wine glass is closer to life, but the tuning fork is more professional”

TABLE IV. Preference by school level.

Group	Household (A)	Lab (B)	No preference	Total
Secondary	50 (52.1%)	17 (17.7%)	29 (30.2%)	96
College	118 (61.5%)	26 (13.5%)	48 (25.0%)	192

Note. $\chi^2(2) = 2.36$, $p = 0.308$; Cramér's $V = 0.090$ (small).

and (b) their item-specific ratings of the two demonstrations differ between secondary and college cohorts. This comparison is theoretically and practically relevant because perceptions of everyday relevance and what counts as “scientific” may shift with educational experience, potentially changing how strongly students differentiate between demonstrations that present comparable underlying physics.

Table IV summarizes preference choices for the two demonstrations. In both cohorts, the household demonstration (wine glass) is chosen more often than the lab demonstration (tuning fork). To examine whether categorical preference differed by school level, we conducted a Pearson chi-square test of independence on a 2×3 contingency table (secondary vs college $\times$ household/lab/no preference). The test evaluates whether the distribution of preference categories is independent of school level. Alongside the chi-square statistic and p value, we report Cramér's V as an effect-size estimate for the strength of association (with V values in the present study indicating a small association). Secondary students showed a descriptively weaker household preference

and a higher proportion of “no preference” responses than college students. However, the overall preference distribution did not differ significantly by school level, and the effect size was small ($V = 0.090$).

Preference is a global judgment, but the survey also captured seven perception items (interestingness, novelty, clarity, understanding, relevance, scientific authenticity, and stimulating interest in science). To test whether the household-lab rating contrast differs by school level, we conducted a set of mixed (within-between) comparisons for each item, treating demonstration (household vs lab) as a within-participant factor and school level (secondary vs college) as a between-participant factor. The focal inferential quantity is the demonstration $\times$ school level interaction, which directly tests whether the household-lab gap is larger, smaller, or reversed across cohorts. Because seven interaction tests were conducted, interaction p values were adjusted using the Holm procedure.

Across the seven items, the household-lab perceptual pattern is largely consistent across school levels. Six of the seven items show no statistically significant demonstration $\times$ school level interaction after Holm correction (all Holm-adjusted $p \geq 0.298$), indicating that secondary and college students evaluate the two demonstrations in broadly similar ways across most perceptual items. A statistically significant demonstration $\times$ school level interaction is observed for the clarity item after Holm correction (unadjusted $p = 0.00385$; Holm-adjusted $p = 0.0269$). The direction of this interaction differs between cohorts: secondary students rate the lab demonstration as slightly

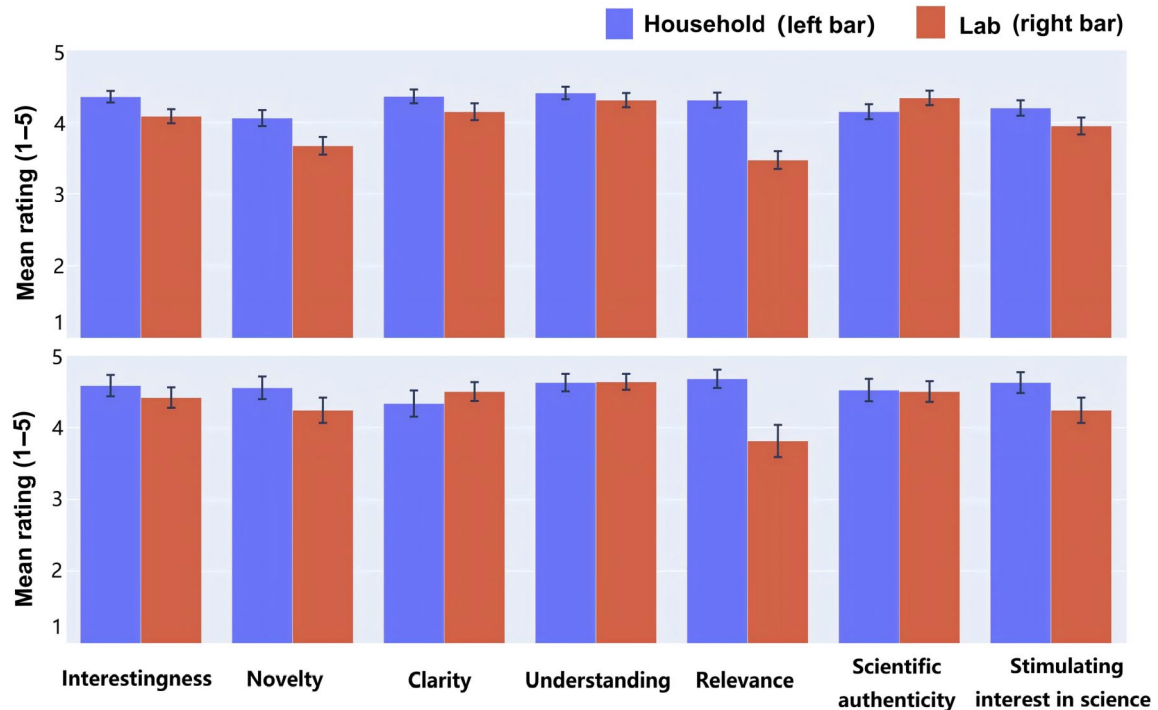


FIG. 2. Mean ratings for household vs lab by school level: Secondary (top) vs College (bottom). Error bars show 95% CI.

TABLE V. Frequency (and percentage) of preference by gender.

Group	Household (A)	Lab (B)	No preference	Total
Male	75 (63.6%)	16 (13.6%)	27 (22.9%)	118
Female	93 (54.7%)	27 (15.9%)	50 (29.4%)	170

$\chi^2(2) = 2.30$, $p = 0.317$; Cramér's $V = 0.089$ (small).

clearer on average, whereas college students rate the household demonstration as slightly clearer on average. Figure 2 provides a visual summary of these patterns by showing mean ratings (with 95% confidence intervals) for household and lab across all items in each cohort.

E. Comparison between male and female students

This subsection examines whether students' preferences and ratings differ by gender. Gender was coded in the dataset as 0 = male and 1 = female. This analysis serves as a subgroup consistency check: if the household advantage depends strongly on gender, instructional design recommendations would need to be qualified; conversely, similarity across genders strengthens the robustness of the findings within the present sample.

Table V reports preference choices by gender. Both male and female students show household as the most frequently preferred option. To test whether preference differed by gender, we applied the same Pearson chi-square test of independence to a 2×3 contingency table

(male vs female $\times$ household/lab/no preference) and reported Cramér's V as the corresponding effect size. This analysis evaluates whether gender is associated with the probability of selecting each preference category rather than focusing only on the household vs lab contrast. The overall preference distribution does not differ significantly by gender, and the effect size is small.

To test whether the household-lab rating contrast differs by gender, we applied the same mixed (within-between) framework used in Sec. III D, focusing on the demonstration $\times$ gender interaction for each item and applying Holm correction across the seven interaction tests.

No item shows a statistically significant demonstration $\times$ gender interaction after Holm correction (all Holm-adjusted $p = 1.00$). This indicates that gender does not meaningfully moderate how students differentiate between household and lab on any of the seven measured items. In practical terms, male and female students exhibit highly similar profiles: household tends to score higher on interest- and relevance-related perceptions, lab tends to score slightly higher on scientific authenticity, and clarity/understanding do not show a strong differential advantage that would suggest preference is driven by ease. Figure 3 visualizes these patterns.

IV. DISCUSSION

A. Student preference and engagement patterns

This study investigated student preferences and perceptions concerning demonstrations of a physics principle

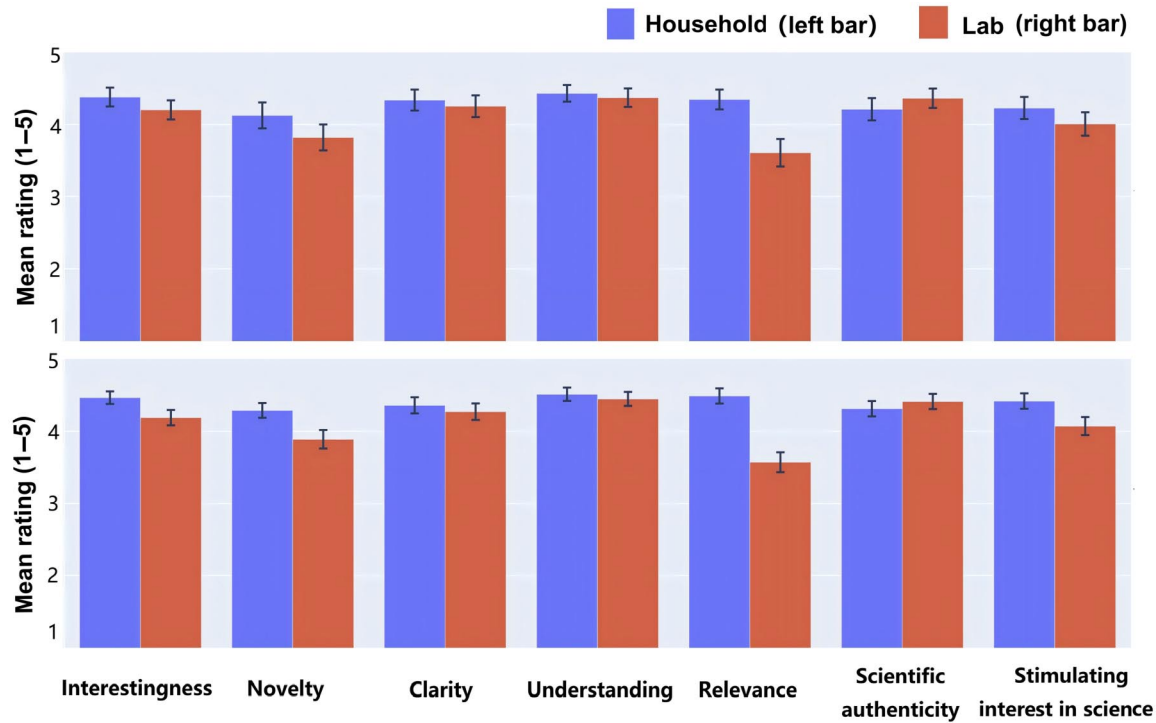


FIG. 3. Mean ratings for household vs lab by gender: Male (top) vs Female (bottom). Error bars show 95% CI.

using household objects versus traditional laboratory equipment. In this resonance demonstration pair, the findings indicate a clear overall preference for the demonstration employing a household object.

The preference distribution itself is notable. A clear majority of students preferred the everyday-object demonstration, while relatively few preferred the laboratory-equipment version. This pattern suggests that demonstrations employing familiar objects may provide an affective advantage beyond simply illustrating the underlying physics phenomenon. Importantly, the absence of any presentation-order effect indicates that this preference reflects genuine differences in how the demonstrations were perceived rather than a simple primacy or recency effect arising from the sequence of presentation.

These results suggest that the choice of materials used in demonstrations can meaningfully shape students' affective responses to physics instruction. While demonstrations are traditionally valued for their conceptual explanatory power, the present findings highlight that the materials themselves may also influence students' engagement and interest.

The wine-glass demonstration was rated significantly higher in interestingness, novelty, relevance to students' lives, and stimulation of interest in science. This strong endorsement aligns with extensive research emphasizing that learning is most effective when contextualized and connected to students' experiences [12,23]. The particularly large difference for perceived relevance underscores the potential of using everyday items to bridge abstract physical principles and students' daily worlds.

Qualitative responses reinforce this interpretation. Many students described the wine-glass demonstration as "closer to real life," suggesting that familiar materials can make physics appear more present in everyday experiences. Such perceptions may increase intrinsic motivation [24] and situational interest [25], both of which are known to support engagement in science learning.

B. The theoretical mechanism: Material versus narrative context

The strong student preference for household objects aligns with constructivist theories, which posit that learning is most effective when new information is anchored to a learner's prior experiences [9,10]. By using familiar objects such as wine glasses, the instructor activates situational interest—a spontaneous, environmentally triggered form of interest that can bridge the gap between a student's daily life and abstract physics [25]. This preference may be further explained through the lens of situated cognition, which argues that the physical environment and the tools used in instruction are not neutral conduits for information but actively situate knowledge within a specific social and material context [26]. When a physics principle is demonstrated using specialized

laboratory equipment, the phenomenon is effectively isolated within a professional, academic realm that many students perceive as distant or belonging to an entirely different world from their own. In contrast, demonstrating the same principle with a household object effectively demystifies the science: it communicates to students that the laws of physics are not exclusive to the controlled environment of a laboratory but are active and observable in the objects of their own homes. This shift reduces the psychological distance between the learner and the subject matter, lowers the affective filter, and makes the conceptual content feel more accessible and personally meaningful.

This observation also contributes to a growing body of work distinguishing between different modes of contextualization in science education. As Wei *et al.* recently demonstrated, contextualized physics problems embedded in real-world written narratives can paradoxically create a "perceptual gap" for older students [27]. In their study, students from the ninth grade onward perceived narrative context as a cognitive burden that increased reading demand and obscured the core physics concepts. Our results suggest that this "contextualization burden" may be specific to the delivery modality. While written context—which by its nature imposes reading demands—can introduce extraneous cognitive load, a physical household object may provide some of the same affective benefits of relevance and familiarity without the linguistic or cognitive complexity of a word problem. Because the present study found no significant difference in clarity or perceived understanding between the two setups, we argue that material-based contextualization may allow instructors to lower the "barrier" to engagement without raising the barrier to comprehension. For older learners in particular, the most effective form of context may be one that is embedded in the physical tools of the demonstration rather than in its verbal or narrative framing.

C. Experimental quality control: Conceptual and observational equivalence

A vital component of the study's validity rests on ensuring that the preference for the household demonstration did not arise from incidental differences in teaching quality or conceptual difficulty. To maintain high internal validity, several experimental controls were implemented.

Regarding instructional consistency, both versions of the resonance demonstration were presented by the same instructor, employed the same explanatory narrative, and lasted the same duration (approximately 5 min). This design ensures that the results cannot be attributed to differences in the instructor's delivery style, enthusiasm, or the depth of conceptual explanation provided.

Regarding conceptual equivalence, the two setups were selected as a complementary pair illustrating the identical

underlying physics—mechanical resonance—with no variation in the complexity of the principle being demonstrated. Crucially, the quantitative data confirm that students rated the two demonstrations similarly in terms of the clarity of the visible phenomenon and their self-reported support for understanding resonance. Neither of the two clarity-related items (clear visibility, helps understanding) showed a statistically significant difference between conditions. This equivalence is of central theoretical importance: if the household demonstration had been rated as easier to see or easier to understand, the observed preference might plausibly reflect differences in instructional effectiveness rather than in affective engagement. The equivalence of clarity and understanding ratings instead suggests that the preference advantage arises mainly from affective dimensions—relevance, novelty, and interest—rather than from any difference in observational accessibility or conceptual ease. The findings therefore speak directly to the question of whether material choice influences student perceptions independent of instructional quality, and the evidence is unambiguous that it does. This interpretation remains limited to students' self-reported perceptions; the present study did not directly measure conceptual learning.

D. Perceptions of scientific authenticity

While the household demonstration showed clear advantages in engagement-related dimensions, the lab demonstration was rated significantly higher on the item “This felt like a science experiment.” This finding reflects the long-standing association in students' minds between specialized apparatus and the formal identity of scientific practice [28,29]. Students frequently characterized laboratory equipment as appearing more “professional,” “rigorous,” and authoritative, suggesting that such materials carry symbolic weight beyond their functional role—they signal membership in a recognizable community of scientific inquiry.

Nevertheless, the household demonstration also received a high mean rating on perceived scientific authenticity ($M = 4.27$), indicating that familiar household objects can still be perceived as scientifically legitimate when they clearly and compellingly illustrate a physical principle. This observation challenges any narrow equation of scientific practice with specialized equipment and aligns with broader calls in science education to make the presence of scientific principles in everyday experience more visible and celebrated [30,31]. Rather than representing mutually exclusive options, the two types of demonstration materials may play genuinely complementary pedagogical roles. Household objects can enhance affective engagement and perceived relevance, bringing physics into students' lived experience; laboratory equipment can reinforce perceptions of scientific precision and professional practice, socializing students into the norms

of the discipline. An informed integration of both within a course may therefore serve students better than an exclusive reliance on either.

E. Consistency across student groups

The comparison of secondary and college students reveals that the appeal of household objects in demonstrations is broadly robust across levels of educational experience. Although college students showed a descriptively stronger preference for the household demonstration, the difference in preference distributions between the two school level groups was not statistically significant, and the household-lab contrast across most perception items remained similar between them. This consistency indicates that the motivational advantage associated with household objects is not a developmental artifact limited to younger or less experienced learners but appears to extend across different stages of physics education—from the introductory high school level through advanced undergraduate and graduate study.

The one exception—the crossover interaction on the clarity item—is worth dwelling on precisely because it is so narrow in scope. Secondary students rated the lab demonstration as slightly clearer than the household demonstration, while college students showed the reverse pattern. This modest reversal likely reflects differences in prior exposure to laboratory apparatus. Students who encountered tuning forks routinely in earlier schooling may find the wine-glass demonstration more novel and thereby more visually salient, while younger students who have had less exposure to formal laboratory equipment may find the tuning fork more clearly organized and predictable. In either case, neither group finds one demonstration dramatically clearer than the other at a magnitude that would alter the overall preference pattern. The convergence of conclusions across school levels lends practical clarity to the findings: instructors at both the secondary and college levels can plausibly expect that incorporating household objects into demonstrations will enhance perceived relevance, novelty, and interest without meaningfully compromising students' ability to observe the phenomenon or grasp the underlying concept.

Similarly, the complete absence of meaningful gender differences—in both preference distributions and all seven perception ratings—strengthens the within-sample robustness of the findings. Male and female students evaluated the two demonstrations in highly similar ways across every measured dimension. This result suggests that the engagement advantage associated with household objects does not depend on gender-related differences in attitudes toward science or prior identification with the discipline. Instructors can therefore reasonably expect the effects documented here to apply broadly across their student population rather than only to specific demographic subgroups.

F. Implications, limitations, and future research

From an instructional perspective, the findings suggest that demonstrations using household objects may serve not merely as entertaining or attention-grabbing alternatives to conventional setups but also as powerful tools for connecting abstract physical principles to the texture of students' lived experiences. When such demonstrations are carefully designed so that the underlying phenomenon remains equally observable, they may enhance affective engagement substantially without sacrificing conceptual clarity or the perceived scientific legitimacy of the instruction.

These results carry a straightforward practical implication: instructors may benefit from intentionally incorporating everyday materials into their demonstration repertoire alongside traditional laboratory equipment. Doing so need not require expensive resources or elaborate preparation; indeed, the advantage of household objects is partly that they are inexpensive, widely available, and carry preexisting associations in students' minds that formal laboratory apparatus simply cannot replicate. Physics instructors who habitually reach for the tuning fork, the cart-and-track system, or the standard optics bench may find it worthwhile to ask whether a functionally equivalent demonstration could be constructed from objects students encounter at home, and based on the evidence presented here, the affective payoff of making that substitution can be substantial.

These findings also raise questions that extend beyond the scope of the present study and merit systematic investigation. The study focused on a single physics concept—mechanical resonance—within a particular educational and cultural context. More specifically, it compared one carefully matched and pedagogically typical demonstration pair: wine glasses and tuning forks. Therefore, the findings should not be interpreted as proving that household objects are superior to laboratory equipment across all physics demonstrations. At the same time, the comparison was not an idiosyncratic case: it represents a common instructional contrast between a familiar household object and a conventional laboratory apparatus used to demonstrate the same physical principle. The results therefore provide a reasonable basis for expecting similar affective advantages in other cases where a household object is familiar to students and can make the target phenomenon as clearly observable as standard laboratory equipment. Whether similar preference patterns emerge across a broader range of physics topics, demonstration formats, and institutional settings remains an important empirical question. Certain phenomena may not lend themselves to household-object demonstrations with the same practical ease, and it would be valuable to identify which topics are most amenable to this approach and under what conditions the household advantage is most pronounced. In addition, although many students in

the present sample treated wine glasses as familiar household objects, wine glasses may not be equally familiar or culturally neutral in all communities. Researchers or instructors applying this approach in other settings should therefore select household objects that are genuinely familiar and meaningful to their own students.

In addition, while the present study rigorously documents students' perceptions and preferences, it does not directly measure whether demonstrations using household objects produce superior conceptual learning outcomes. The item “helped me understand resonance” should therefore be interpreted as self-reported support for understanding not as a direct measure of conceptual learning. The equivalence of clarity and self-reported understanding observed here is consistent with the interpretation that affective engagement is enhanced without cognitive cost, but a stronger test would involve pre- and postdemonstration assessments of conceptual knowledge and longer-term retention. Future work should also explore whether the motivational benefits associated with everyday-object demonstrations translate into sustained increases in science interest or course engagement over the arc of a full semester. Finally, extending the study design to include students from other cultural and institutional backgrounds would help establish whether the preference for familiar objects is a universal feature of learner psychology or one shaped significantly by cultural context and prior educational experience.

Finally, because students evaluated the two demonstrations after observing both versions, their ratings may partly reflect the cumulative benefit of seeing two complementary demonstrations. The counterbalanced order helps reduce systematic order bias, but the present design cannot fully separate the perceived contribution of each individual demonstration from the possible benefit of experiencing the pair.

V. CONCLUSION

Although classroom demonstrations are widely used in physics teaching, the influence of demonstration materials themselves—whether familiar household objects or specialized laboratory equipment—has rarely been examined empirically with the experimental controls needed to isolate material type as the focal variable. The present study provides clear and convergent evidence for a strong student preference for the wine-glass resonance demonstration over the tuning-fork resonance demonstration. The wine-glass demonstration was preferred by 58.3% of students, compared with only 14.9% who preferred the tuning-fork demonstration. This preference was consistent across both secondary and college students and was essentially identical for male and female students, indicating that the finding is robust within the studied population.

The wine-glass demonstration was rated significantly higher in interestingness, novelty, everyday relevance, and

stimulation of interest in science. Critically, no significant differences were observed in perceptions of clarity or self-reported support for understanding resonance, indicating that the preference advantage is rooted mainly in affective engagement rather than in a perceived difference in observational accessibility. Students' written comments corroborated this pattern, with relatability and novelty emerging as the dominant themes in favor of the wine-glass demonstration, while perceptions of professional rigor, reliability, and safety underpinned many favorable evaluations of the tuning-fork demonstration.

These results carry a clear and practical message for physics educators: the choice of demonstration materials is not a peripheral detail of lesson preparation but a pedagogically consequential decision that can meaningfully shape how students relate to physical concepts. In this resonance demonstration, a seemingly simple substitution—using a

recognizable household object in place of a conventional laboratory apparatus as the focal material—substantially enhanced students' sense that physics is relevant to their own lives and their interest in the subject, without any perceived cost to their ability to observe the phenomenon clearly or understand the principle it illustrates. Although the study examined only one carefully matched resonance demonstration pair, the findings show that, when a household object can display a physical phenomenon with comparable clarity, it can do more than entertain: it can help students see physics as something that lives not only in laboratories but also in the familiar world around them.

DATA AVAILABILITY

The data that support the findings of this article are openly available in Ref. [32].

APPENDIX: QUESTIONNAIRE

We just saw two demonstrations about the phenomenon of “resonance.” Demonstration A used wine glasses, and Demonstration B used tuning forks. This questionnaire is anonymous, and your answers will be very helpful for educational research.

1. Part 1: Basic information

(Please check the appropriate box or fill in the information)

Your year of study is:

- ☐ High School Year 1
- ☐ High School Year 2
- ☐ High School Year 3
- ☐ Undergraduate Year 1
- ☐ Undergraduate Year 2
- ☐ Undergraduate Year 3
- ☐ Undergraduate Year 4
- ☐ Graduate Student or Other: _____

Your age is _____ years old

Your gender is: ☐ Male ☐ Female

2. Part 2: Overall preference

Overall, which demonstration did you prefer? (Please choose only one)

- ☐ Demonstration A (Wine Glass)
- ☐ Demonstration B (Tuning Fork)
- ☐ No strong preference/Liked both about the same

Please briefly explain the main reason for your choice above:

3. Part 3: Evaluation of both demonstrations

Based on your feelings about the two demonstrations, please circle the appropriate number for each statement below (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree).

A. Regarding Demonstration A (Wine Glass):

Aspect	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
This demonstration was very interesting	1	2	3	4	5
This demonstration was very novel	1	2	3	4	5
The phenomenon was easy to see clearly	1	2	3	4	5
It helped me understand resonance	1	2	3	4	5
I feel it was relevant to my life	1	2	3	4	5
It felt like a “science experiment”	1	2	3	4	5
It made me more interested in science	1	2	3	4	5

B. Regarding Demonstration B (Tuning Fork):

Aspect	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
This demonstration was very interesting	1	2	3	4	5
This demonstration was very novel	1	2	3	4	5
The phenomenon was easy to see clearly	1	2	3	4	5
It helped me understand resonance	1	2	3	4	5
I feel it was relevant to my life	1	2	3	4	5
It felt like a “science experiment”	1	2	3	4	5
It made me more interested in science	1	2	3	4	5

4. Part 4: Open-ended questions

What do you think are the advantages of using everyday objects (e.g., wine glass) for science demonstrations?

What do you think are the advantages of using lab objects (e.g., tuning fork) for science demonstrations?

Do you have any other thoughts or suggestions about today’s demonstrations or this survey?

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