Journal of Teaching and Learning with Technology, Vol. Vol. 13, Special Issue, pp.49-69.
doi: 10.14434/jotlt.v13i1.37995

Integrity of Best-Answer Assignments in Large-Enrollment Classes: The Role of Compulsory Attribution

Kurt Schmitz
Georgia State University
kschmitz1@gsu.edu

Veda C. Storey
Georgia State University

Abstract: Many instructional methods that focus on analytical, skill, and competency development have a single or small set of appropriate answers. Best-answer assignments are popular for large-enrollment classes because of the relative ease with which scoring and feedback can be managed at scale. However, cheating is regularly confirmed at disturbingly high levels, with commonly used content-comparison tools unsuited to identify original authors. We present a method to enforce compulsory attribution, enhancing the integrity of best-answer assignments. The method secures compulsory attribution of digital solutions using metadata, access controls, and extensible code available in many common applications, including Microsoft Office. A unique feature that makes this method well suited to large-enrollment classes is the ability to secure and, when necessary, delete stolen work, precluding misappropriation. This method minimizes the bureaucratic burdens associated with academic dishonesty procedures. This study, grounded in routine activity theory, describes a compulsory attribution method, called StartHere, that activates perceived guardianship in the form of interpersonal technical controls and social-ties controls for offline digital assignments. In a field experiment, we collected and analyzed empirical data in the form of qualitative student comments, quantitative survey data, and actual misappropriation events. The findings reported here demonstrate efficacy of both guardianship pathways within large-enrollment classes.

Keywords: digital misappropriation, compulsory attribution, routine activity theory, best-answer assignments, guardianship, technical controls, social-ties controls, psychological ownership, StartHere, cheating

This study addressed plagiarism and authenticity of best-answer analytical, skill, and competency development assignments that are popular in large-enrollment classes. Well-constructed best-answer assignments exercise higher order cognitive thinking skills (AlMahmoud et al., 2015). Best-answer assignments are valued for their reliability, validity, cost-efficiency, and feasibility (Okubuiro et al., 2019) in the disciplines of mathematics (Bennett et al., 2000), programming (Petersen et al., 2016), science (Turiman et al., 2012), medicine (Sam et al., 2019), engineering, business, and data analytics (Horgan, 1978).

Best-answer assignments are increasingly important for eLearning (Webb & Choi, 2014) at the same time as offline eLearning is expanding instruction to underserved communities that lack instructors or access to fast reliable internet (Kyaw et al., 2019; Rasmussen et al., 2014). However, plagiarism is particularly acute when assignments are conducted digitally (Newton, 2024), where it undermines the learning process (Kauffman & Young, 2015). When transitioning assignments to an offline digital form, it becomes apparent that properly rewarding students' efforts and guiding their learning progress with targeted feedback require a robust method to ensure authorship. Conventional plagiarism detection methods compare content and form to a database of reference works. Content-comparison tools target open-format written assignments, such as essays, but perform poorly for best-

answer assignments.

The objective of this research was to restore integrity to digital assignments by demonstrating and evaluating a method to reliably identify authorship in offline digital environments. Guided by routine activity theory, we provide a compulsory attribution solution that embraces both technical controls and social controls to prevent and expose misappropriation. Our solution, called StartHere, captures and secures authorship and prevents tampering with solutions created offline in digital form. A field experiment provided empirical support for efficacy along with behavioral insights into digital malfeasance.

Related Literature

Best-Answer Assignments

Best-answer assessments take many forms, including fill in the blank, multiple choice, and multiple selection. This type of question is commonly used for summative assessments and serves a formative role when used to practice recall. Multiple selection (sometimes called multiple-answer multiple choice) provides more insight into a student's partial understanding and is useful when formative feedback is desired (Petersen et al., 2016). These forms of best-answer assessments provide their primary value for recall and comprehension.

Many learning objectives targeting application, analysis, and evaluation that emphasize skill and competency are best suited to process-oriented assignments (Hunter & Kovarik, 2022; Tarvin & Al-Arishi, 1991) *Task-oriented activities* lead students to discover solutions themselves, by using either inductive or deductive reasoning to solve a problem, answer a question, resolve a conflict, exemplify a rule, or form a principle. *Process-oriented* activities stress the value of the process; mastering the process can be more important than the solution generated. Process skills develop through repeated practice of data interpretation, problem solving, and critical thinking (Hunter & Kovarik, 2022). Mathematics introduced "word problems" (Lestari, 2022). Students must assess information and a focal question, then apply process-oriented skills and competencies to generate an appropriate answer. This type of best-answer assignment lends itself to documenting preliminary steps that demonstrate a grasp of the applicable processes. The process can be as rudimentary as long division or more sophisticated, such as a debt-to-equity calculation or regression.

Social Nature of Learning and Activity Theory

Skill and competency development are not simply individual achievements but occur in a social environment among a community (Russell, 2004). Students, inevitably, and often as part of an instructional methodology, share ideas. Therefore, educators providing individual feedback, and scores, need reliable attribution. The social nature of learning is a highly influential educational perspective championed by Lev Vygotsky (O'Hara, 2006). Vygotsky asserted that higher mental functions develop through social interaction, and development cannot be separated from its social context. The social nature of learning includes "vicarious learning," whereby students learn when observing the behavior and performance of others (Mayes, 2015).

Activity theory builds on Vygotsky's ideas to describe conscious learning as interactive and interdependent with activity, making it both intellectual and social. Activity theory provides a systems framework with six elements (Russell, 2004), depicted in Figure 1. Within educational activity systems, students are the *subjects*. *Objects* are the tasks that educators assign to students. *Tools* are the applications, computers, devices, and processes a student uses to transform an object (the assignment) during a

learning activity. Subjects, tools, and objects converge in a production process leading to the transformation of an assignment into an *outcome* solution. An implicit outcome is the transformation of the student who acquires knowledge, skills, and abilities (Jonassen, 2002).

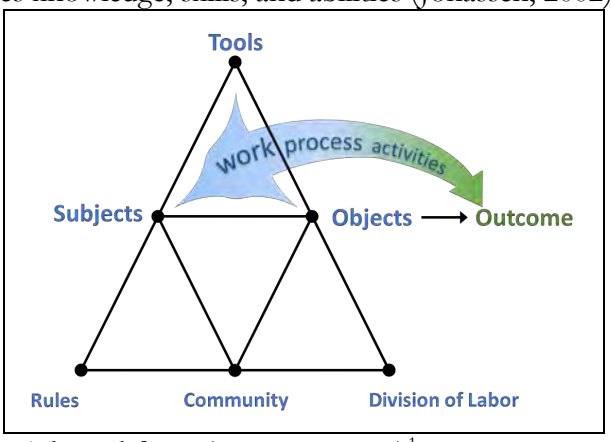


Figure 1. Activity theory. Adapted from (Jonassen, 2002)[1].

Rules guide the production process by prescribing schedules, methods, formats, tools, and behaviors that are expected and acceptable. Explicit rules originate from the educator; implicit rules may be inherent in the culture or setting. A student has access to a *community* of supporting resources including tutors, mentors, parents, friends, and other students. *Division of labor* recognizes the distinct role of all participants.

Routine Activity Theory

Elements of activity theory provide mechanisms through which deviant behavior enters the work process in the form of tampering, misappropriation, and plagiarism. Routine activity theory (Wilcox et al., 2003) models phenomena that conspire to facilitate deviant activity and suggests mechanisms to control that activity. Deviant behavior occurs when (1) the actor (a student or subject) is motivated; (2) there is a suitable target (a solution or outcome); and (3) there is a lack of perceived obstacles that guard the object from misappropriation (rules and tools).

The prevalence of *motivated offenders* is well documented among university students where cheating is regularly confirmed at disturbingly high levels (Curtis & Tremayne, 2021). Two facets of suitable targets (Wilcox et al., 2003) are worthy of scrutiny. The first is a target's *perceived vulnerability*. A target work product in a form that cannot easily be exploited is an unattractive target. Targets are unlikely to be perceived as vulnerable when tampering requires specialized skills unavailable to a perpetrator, regardless of high motivation. The second is *antagonism* toward the activity or entity it represents. A student who judges an assignment to be overly easy or exceedingly difficult may conclude the activity is punitive and be antagonistic toward it.

Guardianship refers to actual and perceived controls that protect a target (Wilcox et al., 2003). *Interpersonal control* includes direct supervision or technical interventions that constrain available action. This can take the form of sufficiently credible imagined constraints that serve as a deterrent. Alternately, guardianship may take the form of *social ties* that influence potential perpetrators. The ties manifest as social influences that make norms or rules effective (Groff, 2015). Relationships

[1] Used with permission of Educational Technology Publications, Inc, from Educational Technology volume 42, issue 2, page 47, 2002. Permission conveyed through Copyright Clearance Center, Inc.

established for a non-control purpose are *indirect social controls* when they induce conformance to social norms as a by-product. This form of guardianship is linked to social arrangements that "make the offender less likely to take advantage of chances to commit crime that are already available" (Schaefer & Mazerolle, 2017, p. 7).

Threats to Digital Content

Students who undertake digital plagiarism are pursuing work avoidance and seek to complete an assignment with minimal time and effort (Kauffman & Young, 2015). Routine activity theory predicts deviant behavior when perpetrators (students) are motivated, there exist suitable targets (a digital assignment solution), and guardianship is limited. Misappropriation becomes cheating when solutions created by one student are submitted as the work of a perpetrator. Perpetrators undermine the integrity and trustworthiness of digital information when they make improper content modifications or tamper with author identity (Harley & Cooper, 2021). Figure 2 juxtaposes content tampering and metadata tampering to categorize threats to digital information. These threats capture the methods perpetrators use to present the digital work of others as their own and identify attack vectors to be addressed.

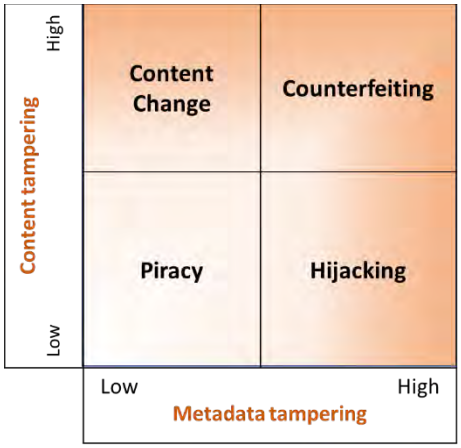


Figure 2. Threats to digital content.

Piracy (simple theft) involves little or no modification of content or metadata. Easily replicated digital products are captured, copied verbatim, and inappropriately used, in part or in full. *Content change* involves modification or manipulation of content. These changes delegitimize digital products when used to hide original authorship. *Hijacking* involves modification or manipulation of metadata to hide or alter attribution while leaving the core content unchanged. *Counterfeiting* involves creation of or tampering with both content and metadata to make fake products appear genuine.

Empirical Study of Compulsory Attribution

Content-comparison tools are unable to reliably determine the original author of best-answer assignments where high similarity is the norm. Proctors may be an option for high-stakes assessments but are impractical for routine digital assignments in large-enrollment classes. This study demonstrates the efficacy of compulsory attribution as a plagiarism countermeasure at scale for digital assignments (both online and offline).

Compulsory Attribution

We formalized compulsory attribution as a set of policies and rules that consistently identify the author and protect the content. We implemented our prototype, StartHere, to enforce these policies and rules during assignment execution and solution creation. The rules are provided in Table 1, with implementation decisions employed to create the prototype.

Table 1. Compulsory attribution policy rules and StartHere implementation.

Policy rule	Implementation
Use a code-extensible application for all assignments.	Microsoft Excel with Visual Basic
Provide data and templates for assignment solutions (work product).	Excel Starter files with "very hidden" worksheets for data and solutions (work product)
Implement a signing ceremony to capture then secure author identity during solution creation.	Visual Basic code embedded in Starter files implements a signing ceremony to collect author identity and a private identifier stored as protected metadata
Reveal data and templates after author identity is captured.	Visual Basic code reveals "very hidden" worksheets with data and solution templates after author identity is secured
Insert steganographic watermarks within work products.	Visual Basic code encodes author identity and embeds watermarks within solution templates
Monitor metadata and apply countermeasures.	Visual Basic code monitors author identity metadata. Attempts to alter authorship activate logging and self-destruct (automated deletion of data and solutions)

StartHere is implemented using Excel, a choice well suited for many offline skill-building assignments and a code-extensible platform upon which to layer security countermeasures. A valuable and unique characteristic of this implementation is the ability to assign tasks to be performed offline in digital form. This approach embeds the compulsory attribution rules in the same digital file as the assignment solution. The Excel file becomes a portable container with attribution rules, enforcement, and content protection integrated with the digital solution wherever it is replicated and transported. The result ensures integrity where the instructional method requires accurate attribution for feedback and scoring.

Excel Starter files are provided for assignments. They include Visual Basic code, data worksheets, and solution worksheets. The solution worksheets provide a template where students record each progressive step of the assignment activity, including the final solution. Elaboration of intermediate steps allows the educator to provide detailed feedback and establishes the structure to support steganography. Author identity is visible to anyone opening the file, but other metadata (including private identifiers) are hidden. Compulsory attribution code monitors identity data and takes protective measures when attempts are made to remove or alter the original author's identity. Protective measures when hijack attempts are detected include (1) deleting all worksheets with partial or complete solutions; (2) saving the file with deleted content removed; and (3) displaying an alert message indicating that the assignment must be restarted with a new Starter file. Enforcing these rules ensures that the submitted work is correctly attributed. Attempts to modify the author's identity (attempts to hijack a solution created by another student) will delete that solution, leaving the perpetrator with nothing to submit. Attempts to copy/paste solutions from other students' work files will also embed steganographic watermarks identifying the original author. The Appendix provides

details of the StartHere prototype.

The compulsory attribution method can be implemented in other code-extensible applications. Most Microsoft Office applications are code extensible with Visual Basic. Other common applications are similarly code extensible, such as various web browsers with JavaScript.

Research Hypotheses

Our hypotheses emphasize the guardianship mechanisms outlined by routine activity theory (Wilcox et al., 2003). This study examined user perceptions, as is common for research measuring the social and behavioral effects of a software artifact (Yang et al., 2012). Perceptions provide insights into the mechanisms through which direct interpersonal constraints influence deviant behavior. Perceptions are particularly relevant for the social-ties dimension of guardianship. Perceived guardianship is modeled as a mediating variable through which antecedent controls influence misappropriation. This leads to our first hypothesis (H):

H1: Perceived guardianship is negatively associated with misappropriation.

Guardianship—Interpersonal and Technical Controls

Technical controls impose direct constraints to preclude actors from copying and submitting another person's digital solution. An example of interpersonal control is the use of proctors to monitor students during assessments. Technical controls can decrease misappropriation in a variety of ways that preclude access to inappropriate resources and content. For example, lockdown browsers limit freedom of action during high-stakes online assessments. Technical controls can also take the form of software-enforced rules implementing compulsory attribution on digital solutions obtained from other students, leading to the following:

H2a: Technical controls are negatively associated with misappropriation.
H2b: Perceived guardianship mediates the effects of technical controls on misappropriation.

Guardianship—Social Ties

Social ties integrate social norms and indirect social controls. Interventions that amplify an actor's commitment to valued social institutions can elevate a student's sense of ownership for their role and duties. Psychological ownership is the sense of possession an individual holds for material and immaterial objects (Jussila et al., 2015). A person's name is the most powerful symbol of self-identity (Koole & Pelham, 2003). Having a student attach their name to assignments is one way to strengthen their sense of ownership. A protocol that makes this ceremony explicit is a manipulation of psychological ownership to amplify social ties. Psychological ownership is positively associated with motivation, self-esteem, and performance (Van Dyne & Pierce, 2004). It is also associated with custodianship and stewardship (Wiggins, 2018), with direct implications for guardianship. Interventions that amplify psychological ownership discourage misappropriation of other students' work, leading to the following:

H3a: Psychological ownership is associated with decreased misappropriation.
H3b: Perceived guardianship mediates the effects of psychological ownership on misappropriation.

Research Model

Figure 3 shows the model used to assess the mechanisms through which StartHere impacts perceived guardianship to influence misappropriation.

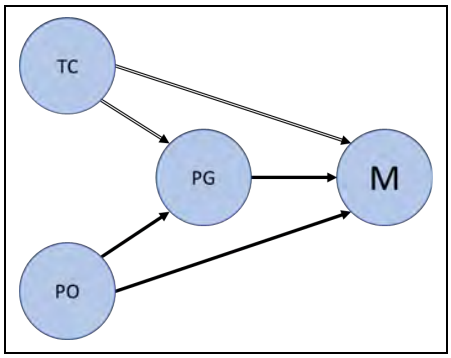


Figure 3. Research model. M = Misappropriation; PG = perceived guardianship; TC = technical controls; PO = psychological ownership.

Method

To evaluate compulsory attribution, we conducted a series of testing and refinement cycles of the StartHere prototype, culminating in a field experiment. Three cycles of development and refinement were conducted to implement the guardianship methods guided by routine activity theory. Each revision cycle involved large-enrollment introductory information systems classes and low-stakes weekly assignments (e.g., rudimentary Excel assignments).

The first cycle employed StartHere access logging and exposed 20 instances of piracy (where the names of other students were identified in the event logs) among 1,099 students in a single academic year (1.8% of students). This cycle did not implement a signing ceremony to activate social controls, provided no access controls, and lacked watermarking to reveal copy/paste theft, plausibly undercounting misappropriation.

The second cycle provided restrictive technical controls with signing ceremonies and access controls to protect the integrity of solution content and metadata. It also added the self-destruct feature when tampering with author identity was detected, leaving the perpetrator with nothing to misappropriate. This cycle manipulated both technical control and social-ties guardianship. Only four instances of tampering among 1,535 students (0.26%) were observed in this cycle. This cycle also lacked watermarking to expose copy/paste theft, plausibly undercounting misappropriation.

The third cycle added steganographic watermarks to expose copy/paste misappropriation. This cycle also made the author's identity explicit and visible to amplify psychological ownership and social-ties guardianship. This cycle exposed two instances of simple theft and two instances of copy/paste tampering. In total, Cycle 3 exposed four instances of misappropriation among 1,723 students (0.23%). The final semester of Cycle 3 provided the setting for a field experiment.

Before collecting data on our hypotheses, we conducted a set of contingency table tests using the Fisher exact test as implemented in Stata (version 13; StataCorp, 2013). The null hypothesis asserts there is no association between misappropriation with and misappropriation without the use of StartHere. The alternative hypothesis accepts an association between the use of StartHere and a change in misappropriation. When comparing Cycle 1 (baseline condition: no visible treatment) to Cycle 2 (Treatment 1 condition: limited StartHere), the null hypothesis is rejected with a p value of .002, providing strong support that StartHere is associated with a change (in this case a reduction) in

misappropriation. When comparing Cycle 1 (baseline) to Cycle 3 (Treatment 2 condition: full StartHere), the null hypothesis is rejected with a p value of < .000, providing strong support that StartHere is associated with a change (again a reduction) in misappropriation. With this foundation, we proceeded to study the underlying mechanisms through which StartHere affects misappropriation, as predicted in our hypotheses.

Scale Development

Survey scales were content validated using an iterative pre-study. The first step involved a literature search to identify the theoretical basis. The dependent variable was misappropriation, defined as a student's perception of the existence and frequency of copying and submitting assignment solutions created by other members of their community (class or study group). Perceived guardianship items identified specific assignments to focus respondents on guardianship characteristics unique to a specific treatment condition (H1). Interpersonal technical control items used a direct reference to the obvious StartHere controls that appear in Treatments 1 and 2. Technical controls in the form of locked and hidden worksheets as well as deleting solution data in response to tampering were expected to strengthen perceived guardianship (H2). We measured the influence of visible attribution using the self-identity route of psychological ownership proposed by Pierce et al. (2003). The scale emphasizes the degree to which students have a psychological ownership bond with output created for specific assignments. Through this mechanism, signing ceremonies are theorized to trigger social norms associated with class and assignment policies. Amplified social norms are expected to strengthen perceived guardianship (H3).

A qualitative review of survey scale items was performed using a panel of undergraduate teaching assistants (Panel A) to serve as domain experts. Panel A reviewed the survey questions for clarity, completeness, relevance, and adequacy, providing both categorical and free-form qualitative feedback. This qualitative feedback guided Scale Revision 1. Next, a panel of PhD students (Panel B) trained on content validity and prestudy methods rated constructs and items for clarity, congruence, and dependability. These ratings revealed some items with poor content validity. Panel A was interviewed again to discuss problem areas identified in the rating step. These jurists, representative of the target study population, suggested specific changes to better align with the target constructs. Wording adjustments were applied to align the vocabulary and organization of phrases. Panel B ratings and Panel A interviews guided Scale Revision 2. An additional (independent) panel of undergraduate teaching assistants (Panel C) rated the revised constructs for clarity, congruence, and dependability. Some low-performing items were dropped, but there were no further wording changes. The final scales, measurement model statistics, and confirmatory factor analysis are detailed in Table 2. Latent variable means for each phase of the longitudinal study are also provided in Table 2.

Table 2. Measurement model statistics (CFA).

Item	*M*	Load	*SE*	*p* value
Misappropriation (M; dependent variable)				
M1: There is more copying of work on this assignment than on other assignments.	2.28	0.777	—	—
M2: Some students share "individual challenge" solutions on this assignment.	2.77	0.919	0.120	<.01
M3: Some students copy "individual challenge" work on this assignment.	2.63	0.960	0.117	<.01

Item	*M*	Load	*SE*	*p* value
Latent variable				
Baseline	2.86			
Treatment 1	2.55			
Treatment 2	2.54			
Perceived guardianship (PG)				
PG1: It is easier to copy work from another student on this assignment than other assignments. (reverse coded)	4.82	0.939	—	—
PG2: It is easier to submit assignment files from another student on this assignment than other assignments. (reverse coded)	4.88	0.934	0.055	<.01
PG3: Nothing stops students from using work from another student on this assignment.	4.57	0.673	0.088	<.01
Latent variable				
Baseline	3.87			
Treatment 1	4.76			
Treatment 2	4.84			
Psychological ownership self-identity (POSI)				
POSI1: The assignment file I submitted reflects my effort.	5.25	0.762	—	—
POSI2: My work in this assignment represents *me*.	4.99	0.946	0.188	<.01
POSI3: I can identify with my work on this assignment. It is my creation.	5.06	0.873	0.182	<.01
Latent variable				
Baseline	5.05			
Treatment 1	5.10			
Treatment 2	5.14			
StartHere technical controls (SHTC)				
SHTC1: The StartHere process to open data and worksheets, makes sharing work harder on this assignment.	2.78	0.922	—	—
SHTC2: The StartHere process to add a student name makes copying work more difficult.	2.76	0.969	0.040	<.01
Latent variable				
Baseline	n/a			
Treatment 1	2.77			
Treatment 2	2.76			

Note. This table reports confirmatory factor analysis (CFA) statistics for the Treatment 1 condition. Items were rated in an online web survey on 6-point Likert-type scales of 1 (*strongly disagree*) to 6 (*strongly agree*). Nearly identical results were obtained for the other conditions (except technical control was not collected for the baseline condition).

Construct validity was confirmed with a confirmatory factor analysis (CFA; Table 3). All latent variables reported variance inflation factors of less than 3.3, indicating that the data were free of common method bias (Kock, 2015). This is supported by a Harmon's single factor analysis, which calculated 0.338 variance explained by a single factor, below the common method bias threshold of 0.50 (Podsakoff et al., 2003).

Table 3. Construct validity statistics (CFA).

Variable	M	PG	POSI	SHTC
M	**0.897**	-0.661	-0.081	-0.236
PG	-0.726	**0.837**	0.102	0.158
POSI	-0.129	0.140	**0.878**	-0.108
SHTC	-0.186	0.106	-0.106	**0.946**
AVE	0.805	0.700	0.771	0.894
ω(α)	0.924 (0.909)	0.875 (0.871)	0.907 (0.892)	0.944 (0.944)
VIF	n/a	1.031	1.030	1.023

Note. This table reports path model statistics for the Treatment 1 study event. Nearly identical results were obtained for the other study events (SHTC not collected for the baseline). **Correlation**s are shown below the diagonal, **covariations** above, and $\sqrt{\boldsymbol{AVE}}$ on the diagonal (in bold). Goodness of fit confirmatory factor analysis (CFA): comparative fit index = 0.952, standardized root-mean-square residual = 0.057, root-mean-square error of approximation = 0.105, $\boldsymbol{\chi}^2$ = 144.2**.** M = Misappropriation; PG = perceived guardianship; POSI = psychological ownership self-identity; SHTC = StartHere technical controls; VIF = variance inflation factor.

Field Experiment

After validating the instrument, we collected longitudinal data on randomly selected students participating in a single-semester field experiment. The target course uses Excel for a series of low-stakes skill development assignments. The participants, 920 students, were invited to answer an anonymous survey regarding assignment solutions, collaboration, sharing, and misappropriation. Participants were randomly assigned to one of two studies, the first involving this compulsory attribution study, the second contrasting measures of pride and craftsmanship with authentic pride for an unrelated study (not reported here). Of the 725 students who provided informed consent, 360 were randomly assigned to this study. Discarding the 115 who failed the attention checks, left a usable sample of 245. External instructors who adopted StartHere provided additional usability feedback.

Results

Qualitative Results—Students' and Instructors' Views of the StartHere Artifact

Open-ended questions allowed students to provide feedback on usability. When asked about the StartHere intervention, students acknowledged they understood its purpose. Representative comments related to the manipulation check are in Table 4.

Table 4. Student manipulation check and efficacy feedback.

Item	Sample comment
Activates feelings of ownership	"This process created more ownership." "It helps to identify ownership." "I like how my name is associated with my work." "This made me make sure that my name was always present on every work product."
Activates feelings of accountability	"If anything, I was glad for its accountability aspect." "Made me accountable." "This made sure that each student was accountable for their own assignment." "It's a thing for the prof to see whose work it is, and I respect it."
Effective at reducing theft, tampering, and misappropriation	"It seemed like a good way to prevent cheating." "I found it fine to prevent plagiarism." "I liked the anti-cheat." "I think this was a good way of validating authenticity of one's work and reducing cheating." "This forced everyone to do their own work, which I think it is a good thing so people can't turn in the same excel file from one person." "I think it gave a little bit more of an incentive to do all of our own work instead of using someone else's files if we missed a class or something like that." "It made me do my own work and keeps people from cheating (WHICH IS SO NICE)." "I do feel like having StartHere function prevented cheating from other students." "The StartHere function seems to me, to be a way of catching those who think they can 'outsmart' the system." "I liked how it encourages people to work for answers opposed to copying off of someone else." "It was a cool way to track if you actually did the work."

This confirmed that students recognized the StartHere intervention and understood its purpose. It serves as a manipulation check that the treatment was explicit for students and could be expected to influence student perceptions of interpersonal controls and social-ties controls.

Although the primary purpose of StartHere is guardianship, the associated interventions should not simultaneously undermine the learning and measurement objectives of assignments. Feedback from students revealed the StartHere intervention did not interfere with their ability to create assignment solutions. Table 5 summarizes students' views of how the StartHere artifact affected participation.

Table 5. Student usability feedback.

Item	Sample comment
No impediment to content creation	"Did not hinder participation." "It didn't really change my participation." "It was fine." "It was an easy ask."

Item	Sample comment
	"It did not affect my participation in the class."
	"It was a great idea."
Facilitated participation	"I liked the formality of it, and I believe it kept a degree of organization to each assignment."
	"Made you actually do it."
	"It improved my participation for sure."
	"I had to participate more."
	"Increased participation."
	"It affected my participation in a good way."
	"It definitely made me do my assignments."
	"High participation in class."
	"I am sure it motivated some [slackers] to attend class and get their work done."

Students consistently associated the act of compulsory attribution, identifying themselves as author, as reinforcing the policy restricting misappropriation of someone else's work. This qualitative data supports the conclusion that the design is feasible and effective in amplifying perceived guardianship.

Interviews with external instructors (large-enrollment business management course) provided usability insight from the standpoint of educators. StartHere required instructors to complete a configuration exercise to identify places and methods for watermarks and steganography. This setup is required for each additional assignment. Several comments indicated the process is considered a burden: "I get them all set up, and then if the next semester [I] change something, it's like, OK, how do I do [the set up]? You know, it's not exactly easy" and "It wasn't as user-friendly to get working with a given assignment as you needed, based on the dynamics of your class." This instructor noted that she stopped using StartHere for low-stakes assignments, "I quit using it more as we were still changing the Excel worksheets," and focused on high-stakes projects, "I would go back and where I would use it [for] the project…. To prevent cheating on the project is a bigger deal." Nevertheless, external instructors did confirm the value of StartHere: "We did have some [misappropriation] at the beginning" and "It became more of a, you know, deterrent on the front end."

The qualitative assessment provides strong support that the method does not interfere with the assignment and learning objectives. However, customer-side user-friendliness needs improvement. Overall, these comments support the efficacy of StartHere.

Quantitative Measurement and Analysis

Our longitudinal study collected data across three assignments during one semester. The first, the baseline, measured perceptions early in the course without visible application of controls. This involved hidden event logging, but no visible technical controls, no signature ceremony, and no visible attribution. The second phase (Treatment 1), 1 week later, activated StartHere with visible access controls including self-destruct, an explicit signing ceremony, and visible author identification. This phase measured the effects of interventions targeting both paths of perceived guardianship. The third phase (Treatment 2) also employed StartHere and served as a replication study 2 weeks after Treatment 1. Repeated application of StartHere was expected to increase the salience of the manipulation, strengthen the social norms effects, and demonstrate stability of the survey scale measurement instrument. We employed structural equation modeling techniques to assess model fit (Table 6),

calculate the statistically significant relationships (Table 7) and mediation effects (Table 8). Goodness-of-fit statistics are acceptable for exploratory research for all three phases.

Table 6.

Statistic	Condition		
	Baseline	Treatment 1 (limited StartHere)	Treatment 2 (full StartHere)
Goodness of fit			
CFI	0.941	0.952	0.959
SRMR	0.058	0.057	0.045
RMSEA	0.139	0.105	0.096
χ^2	138.04	144.20	127.44
R^2	0.70	0.80	0.76

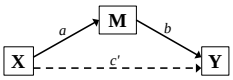
Note. Statistics calculated using structural equation modeling (R & lavaan 0.6-15). Level of significance determined by bootstrapping 500 times to calculate standard errors and *p* values. CFI = Comparative fit index; SRMR = standardized root-mean-square residual; RMSEA = root-mean-square error of approximation.

Table 7.

Direct effect	Condition					
	Baseline		Treatment 1 (limited StartHere)		Treatment 2 (full StartHere)	
	β_0	*p* value	β_1	*p* value	β_2	*p* value
H1: PG $\xrightarrow{(-)}$ M	-0.692	<.001	-0.606	<.001	-0.689	<.001
H2a: TC $\xrightarrow{(-)}$ M	n/a	n/a	-0.068	.017	-0.079	.013
H3a: PO $\xrightarrow{(-)}$ M	-0.127	.129	-0.053	.391	-0.070	.406
TC $\xrightarrow{(+)}$ PG	n/a	n/a	.084	.063	.002	.970
PO $\xrightarrow{(+)}$ PG	-0.186	.296	.224	.028	.209	.027

Note. Statistics calculated using structural equation modeling (R & lavaan 0.6-15). Level of significance determined by bootstrapping 500 times to calculate standard errors and *p* values. The β coefficients are standardized. H = Hypothesis; PG = perceived guardianship; M = misappropriation; PO = psychological ownership; TC = technical control.

Table 8.

Mediation 	Condition					
	Baseline		Treatment 1 (limited StartHere)		Treatment 2 (full StartHere)	
	$\hat{\alpha}\hat{\beta}_0$	*p* value	$\hat{\alpha}\hat{\beta}_1$	*p* value	$\hat{\alpha}\hat{\beta}_2$	*p* value
H2b: TC $\xrightarrow{(+)}$ PG $\xrightarrow{(-)}$ M	n/a	n/a	-0.051	0.089	-0.003	0.687
H3b: PO $\xrightarrow{(+)}$ PG $\xrightarrow{(-)}$ M	0.129	0.306	-0.136	0.026	-0.139	0.040

Note. The mediation path diagram models an independent variable (X), a mediator (M) and the outcome variable (Y). In our analysis perceived guardianship is the mediator; misappropriation is the

outcome; psychological ownership is an independent variable; technical control is an independent variable. Statistics calculated using structural equation modeling (R & lavaan 0.6-15). Level of significance determined by bootstrapping 500 times to calculate standard errors and *p* values. The $\hat{\alpha}\hat{\beta}$ values were calculated using the delta method (Sobel, 1982).

Perceived guardianship is a general concept and captures any perceived cultural, social, interpersonal, or technical influence that discourages misappropriation. Perceived guardianship had a direct negative relationship with misappropriation in all three phases (Table 7). This provides strong and stable support for H1.

At baseline the assignment had an implicit signature (no visible attribution) and no apparent technical controls. Psychological ownership had no significant relationship with perceived guardianship or with misappropriation (Table 7) and no significant mediated effect through perceived guardianship to misappropriation (Table 8). This baseline measure provides a reference to contrast the influence of StartHere.

During Phases 2 and 3, StartHere technical controls and visible attribution took effect. Perceived guardianship continued to have a strong negative relationship with misappropriation. These phases introduced technical controls as access control, metadata protection, and tamper-triggered self-destruct. Technical controls now had a significant negative relationship with misappropriation (Table 7), providing support for H2a. However, they had no effect on perceived guardianship (Table 7); nor was there an indirect effect on misappropriation through the mediating variable perceived guardianship (Table 8). As a result, H2b is not supported.

Psychological ownership was triggered by signing ceremonies and visible attribution during both treatment phases. When modeled with the intervening variable, psychological ownership had no direct effect on misappropriation (Table 7). However, there was a significant direct effect on perceived guardianship (Table 7) and a significant indirect effect on misappropriation mediated by perceived guardianship (Table 8). Analysis demonstrates that psychological ownership was fully mediated by the intervening variable perceived guardianship. These results suggest rejecting H3a and accepting H3b.

Discussion

We proposed a method to improve integrity of best-answer assignments to restore confidence in offline digital assignments. The experiment demonstrates the effectiveness of compulsory attribution, implemented by StartHere, to control misappropriation of digital assignments (see Table 9).

Table 9. Summary of conclusions.

Hypothesis	Baseline	Treatment 1	Treatment 2
1: Perceived guardianship $\overset{(-)}{\longrightarrow}$ misappropriation	Accept	Accept	Accept
2a: Technical controls $\overset{(-)}{\longrightarrow}$ misappropriation	—	Accept	Accept
2b: Technical controls $\overset{(+)}{\longrightarrow}$ perceived guardianship $\overset{(-)}{\longrightarrow}$ misappropriation	—	Reject	Reject
3a: Psychological ownership $\overset{(-)}{\longrightarrow}$ misappropriation	n.s.	Reject	Reject
3b: Psychological ownership $\overset{(+)}{\longrightarrow}$ perceived guardianship $\overset{(-)}{\longrightarrow}$ misappropriation	n.s.	Accept	Accept

Perceived guardianship was the most consistent factor influencing misappropriation. In the absence of transparent and visible attribution, psychological ownership in the form of social-ties control was not significant. However, the intervention of signing ceremonies and visible attribution activated social-ties control, which was fully mediated by perceived guardianship. This reinforces the idea that attribution is a social mechanism that draws on perceptions involving interactions with other students. In addition, interpersonal technical controls directly constrained behaviors with a direct influence on misappropriation that did not depend on social influence interaction of other students.

Limitations and Implications for Educators

The compulsory attribution method does not prevent students from verbally and visually sharing ideas, strategies, and specifics for process-oriented assignments. compulsory attribution does, however, limit and expose the direct theft and submission of digital solutions created by other students. This puts a potential perpetrator into a position where they need to replicate the ideas, strategies, and solution specifics demonstrated by other students to generate their own solution. Although this may appear to be a limitation that undermines the instructional and learning value of best-answer assignments, it supports the methods and value of vicarious learning. Multiple studies have found higher learning outcomes when learning includes a collaborative component, rather than individual work alone (Barrett et al., 2021).

A second limitation is that this study does not provide guidance to properly construct best-answer assignments with the context and texture needed to fully engage higher order cognitive thinking (AlMahmoud et al., 2015). However, it is likely that improved integrity of this instructional method will encourage educators to invest the time needed to create high-quality assignments of this type. In addition, StartHere describes the structure (solution templates in Excel) that facilitates recording the intermediate steps in process-oriented assignments, enabling instructors to provide detailed feedback and partial credit where appropriate. Protecting attribution and solutions is particularly valuable in large-enrollment classes where proctoring at scale is impractical.

Conclusion

This research focuses on assigning attribution to student assignments—specifically, the integrity of best-answer and offline digital assignments in large-enrollment classes. Our work examines compulsory attribution and implements a system (StartHere) to ensure it. The social nature of learning and routine activity theory led to the development of the method and hypotheses. The research was conducted longitudinally with statistically significant results for large-enrollment classes, suggesting that compulsory attribution strategies provide effective control of misappropriation.

Acknowledgments

The human subjects research was approved by the Institutional Review Board (IRB) of Georgia State University (IRB no. H19515) as an Exempt Protocol Category 1 & 2.

Appendix

Appendix. StartHere Artifact.

The StartHere prototype uses Excel as a tool for content creation and macro-enabled Excel worksheets as the container that binds code to enforce compulsory attribution with data and solution templates. Figure A1 depicts the architecture of the container encompassing a worksheet named StartHere where students enter their author identity along with a "something they know" credential (a verifiable ID known to both student and instructor, such as a student ID). More sophisticated authentication, such as biometrics, could also be implemented. Other worksheets with instructions, data, and solution templates are unavailable until the embedded Visual Basic for Applications (VBA) code secures student identity (Figure A1, Arrow A). User identity, computer name, and associated metadata are logged in a secured and hidden worksheet (Figure A1, Arrow B).

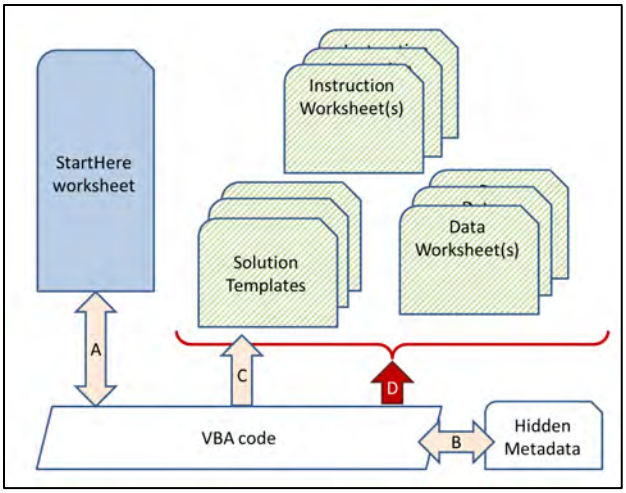


Figure A1. StartHere components. VBA = Visual Basic for Applications.

After the author's identity is captured, a set of worksheets with data, instructions, and solution templates are changed from *very hidden*[2] and protected, to visible and editable (Figure A1, Arrow C). Author identity metadata is stored in a different concealed and protected worksheet along with additional track-and-trace logging. The VBA code monitors identity and tracking data. Any attempt to change metadata results in deleting solution worksheets or reverting the data and solution worksheets to very-hidden status (a configurable choice by the instructor) and exiting the application (Figure A1, Arrow D).

Figure A2 shows the identity declaration worksheet named StartHere. Users enter their name and authorization credentials (cells C4 and C6), then press the "Start Here" button. This activates the signing ceremony (red arrow and dialog box) where students explicitly declare their status as authors. Additional reinforcement of honor codes can also appear here. This triggers steps to expose concealed worksheets and record metadata in locked locations of the StartHere worksheet (cells E10:G10).

[2] "Very hidden" means the worksheet is not accessible in the regular Excel user interface and ensures the sheet cannot be made visible using the regular Excel user interface. StartHere manages these worksheets with Visual Basic code.

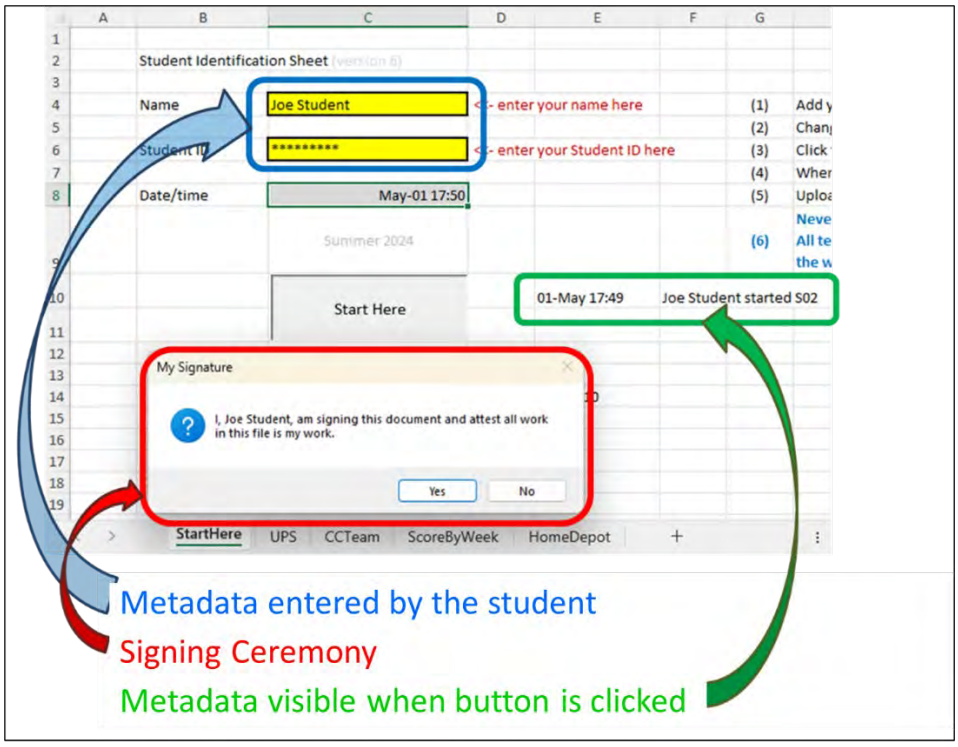


Figure A2. StartHere worksheet.

A copy of identity metadata is secured in a concealed worksheet with a log of access history. Figure A3 provides the contents of a typical log. This worksheet is concealed and password protected. This worksheet establishes a track-and-trace log cataloging the history of a solution file.

Action	Name	Student ID	Date/Time	S02
Start S02	Abo	002-13-0835	01-May 21:10	Abo
Start S02	Mosh	002-98-7902	29-Apr 08:50	C:\Users\a
Start S02	Mos	002-98-7902	28-Apr 19:49	Welcome
Start S02	Mos	002-98-7902	28-Apr 19:49	S02
Start S02	Amb	901-73-0644	28-Apr 16:49	Mos
Start S02	Deri	002-41-2621	28-Apr 15:33	C:\Users\F

Figure A3. Hidden metadata.

Once a solution file (a StartHere container) with author ID is opened, the access control logic monitors metadata for tampering. When attempts to modify metadata are detected, the VBA code performs a self-destruct sequence that deletes all solution worksheets, overwrites the local file with an empty file, and displays the alert message depicted in Figure A4. When a perpetrator sees the alert box, all content has already been deleted and the local disk updated. Clicking OK will quit Excel, leaving the perpetrator without solution content and nothing to submit.

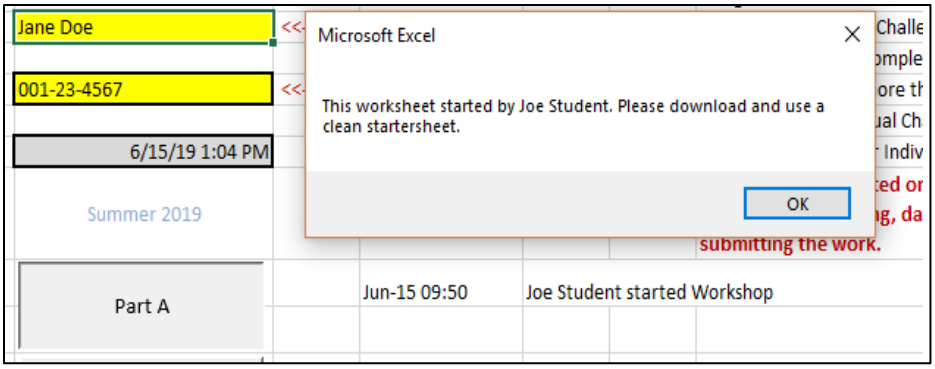


Figure A4. Self-destruct.

In the final revision cycle of StartHere we implemented watermarks and steganography triggered by the signing ceremony. Copies of the author's identity are encoded and concealed in solution template worksheets. Multiple variations of concealed information are possible, including:

- White font on a white background in an otherwise unused cell.
- White font on a white background at the end of other visible text (see Figure A5).
- Concealed in an image (jpg or png) embedded in the worksheet.
- Encoded (a hash value) visible and masquerading as benign data.

Copy/paste replication of solutions from other student files also captures and transports the steganographic watermarks into the perpetrator's file. This allows instructors to expose mule files[3].

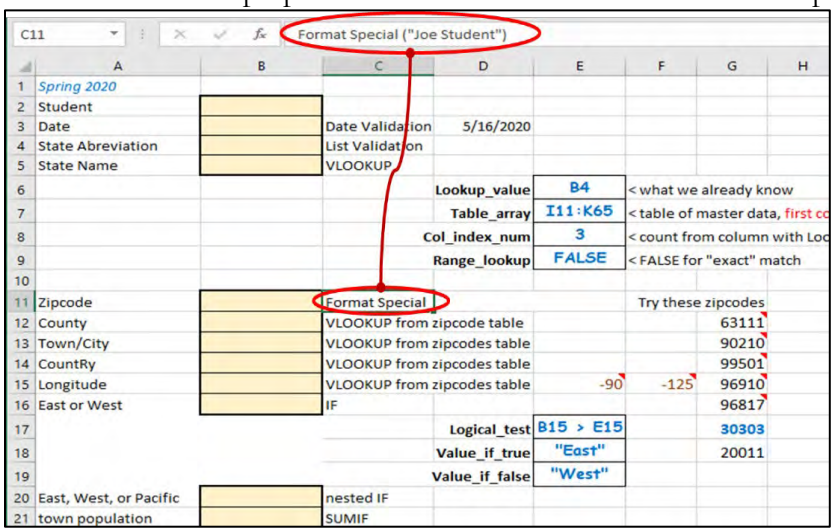


Figure A5. Watermarks and steganography.

[3] A mule file is an Excel file where the metadata is clean, but the assignment work within the excel file has been digitally copy/pasted from another student's file; this is a clean container with dirty content.

References

AlMahmoud, T., Elzubeir, M. A., Shaban, S., & Branicki, F. (2015). An enhancement-focused framework for developing high quality single best answer multiple choice questions. *Education for Health*, *28*(3), 194–200. https://doi.org/10.4103/1357-6283.178604

Barrett, M., Hershock, C., McCarthy, M., Melville, M., & Mertz, J. (2021). What type of debrief is best for learning during think-pair-shares? *Teaching and Learning Inquiry*, *9*(1), 45–60. https://doi.org/10.1177/01466210022031769

Bennett, R. E., Morley, M., & Quardt, D. (2000). Three response types for broadening the conception of mathematical problem solving in computerized tests. *Applied Psychological Measurement*, *24*(4), 294–309. https://doi.org/10.1177/01466210022031769

Curtis, G. J., & Tremayne, K. (2021). Is plagiarism really on the rise? Results from four 5-yearly surveys. *Studies in Higher Education*, *46*(9), 1816–1826. https://doi.org/10.1080/03075079.2019.1707792

Engestrom, Y. (1987). *Learning by expanding: An activity theoretical approach to developmental research*. Orienta-Konsultit.

Groff, E. R. (2015). Informal social control and crime events. *Journal of Contemporary Criminal Justice*, *31*(1), 90–106. https://doi.org/10.1177/1043986214552619

Harley, K., & Cooper, R. (2021). Information integrity: Are we there yet? *ACM Computing Surveys*, *54*(2), Article 33. https://doi.org/10.1145/3436817

Horgan, J. D. (1978). Engineering reality in single-answer problems. *IEEE Transactions on Education*, *21*(2), 65–68. https://doi.org/10.1109/TE.1978.4321197

Hunter, R. A., & Kovarik, M. L. (2022). Leveraging the analytical chemistry primary literature for authentic, integrated content knowledge and process skill development. *Journal of Chemical Education*, *99*(3), 1238–1245. https://doi.org/10.1021/acs.jchemed.1c00920

Jonassen, D. H. (2002). Learning as activity. *Educational Technology*, *42*(2), 45–51. https://www.jstor.org/stable/44428736

Jussila, I., Tarkiainen, A., Sarstedt, M., & Hair, J. F. (2015). Individual psychological ownership: Concepts, evidence, and implications for research in marketing. *Journal of Marketing Theory and Practice*, *23*(2), 121–139. https://doi.org/10.1080/10696679.2015.1002330

Kauffman, Y., & Young, M. F. (2015). Digital plagiarism: An experimental study of the effect of instructional goals and copy-and-paste affordance. *Computers & Education*, *83*, 44–56. https://doi.org/10.1016/j.compedu.2014.12.016

Kock, N. (2015). Common method bias in PLS-SEM: A full collinearity assessment approach. *International Journal of e-Collaboration (IJEC)*, *11*(4), 1–10. https://doi.org/10.4018/ijec.2015100101

Koole, S. L., & Pelham, B. W. (2003). On the nature of implicit self-esteem: The case of the name letter effect. In S. J. Spencer, S. Fein, M. P. Zanna, & J. M. Olson (Eds.), *Motivated social perception: The Ontario symposium*, Vol. 9, pp. 93–116). Lawrence Erlbaum Associates.

Kyaw, B. M., Posadzki, P., Dunleavy, G., Semwal, M., Divakar, U., Hervatis, V., & Tudor Car, L. (2019). Offline digital education for medical students: Systematic review and meta-analysis by the Digital Health Education Collaboration. *Journal of Medical Internet Research*, *21*(3), Article e13165. https://doi.org/10.2196/13165

Lestari, A. P. (2022). Analysis of students' errors in solving the least common multiple and greatest common divisor word problems. *EduMa: Mathematics education learning and teaching*, *11*(2), 191–202. https://jurnal.syekhnurjati.ac.id/index.php/eduma/article/view/9324/4701

Mayes, J. (2015). Still to learn from vicarious learning. *E-Learning and Digital Media*, *12*(3-4), 361–371. https://doi.org/10.1177/2042753015571839

Newton, P. M. (2024). Guidelines for creating online MCQ-based exams to evaluate higher order learning and reduce academic misconduct. In S. E. Eaton (Ed.), *Second handbook of academic integrity* (pp. 269–285). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-54144-5_93

O'Hara, K. E. (2006). Lev Vygotsky. In J. L. Kincheloe & R. A. Horn, Jr. (Eds.), *The Praeger handbook of education and psychology* (Vol. 1, pp. 240–245). Praeger.

Okubuiro, E. O., Ebirim, L. N., & Okoli, C. (2019). Utility of single best answer questions as a summative assessment tool in medical education: A review. *International Journal of Recent Innovation in Academic Research*, *3*, 1–12.

Petersen, A., Craig, M., & Denny, P. (2016). Employing multiple-answer multiple choice questions. In *Proceedings of the 2016 ACM Conference on Innovation and Technology in Computer Science Education* (pp. 252–253). Association for Computing Machinery. https://doi.org/10.1145/2899415.2925503

Pierce, J. L., Kostova, T., & Dirks, K. T. (2003). The state of psychological ownership: Integrating and extending a century of research. *Review of General Psychology*, *7*(1), 84–107. https://doi.org/10.1037/1089-2680.7.1.84

Podsakoff, P. M., MacKenzie, S. B., Lee, J.-Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Rasmussen, K., Belisario, J. M., Wark, P. A., Molina, J. A., Loong, S. L., Cotic, Z., Papachristou, N., Riboli–Sasco, E., Car, L. T., & Musulanov, E. M. (2014). Offline eLearning for undergraduates in health professions: A systematic review of the impact on knowledge, skills, attitudes and satisfaction. *Journal of Global Health*, *4*(1), Article 010405. https://doi.org/10.7189%2Fjogh.04.010405

Russell, D. R. (2004). Looking beyond the interface: Activity theory and distributed learning. In H. Daniels & A. Edwards (Eds.), *Psychology of education* (pp. 309–326). RoutledgeFarmer.

Sam, A. H., Westacott, R., Gurnell, M., Wilson, R., Meeran, K., & Brown, C. (2019). Comparing single-best-answer and very-short-answer questions for the assessment of applied medical knowledge in 20 UK medical schools: Cross-sectional study. *BMJ Open*, *9*(9), Article e032550. https://doi.org/10.1136/bmjopen-2019-032550

Schaefer, L., & Mazerolle, L. (2017). Putting process into routine activity theory: Variations in the control of crime opportunities. *Security Journal*, *30*, 266–289. https://doi.org/10.1057/sj.2015.39

Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. *Sociological Methodology*, *13*(1982), 290–312. https://doi.org/10.2307/270723

StataCorp. (2013). *Stata* (Version 13.1) [Statisitical software].

Tarvin, W. L., & Al-Arishi, A. Y. (1991). Rethinking communicative language-teaching: Reflection and the EFL classroom. *Tesol Quarterly*, *25*(1), 9–27. https://doi.org/10.2307/3587026

Turiman, P., Omar, J., Daud, A. M., & Osman, K. (2012). Fostering the 21st century skills through scientific literacy and science process skills. *Procedia—Social and Behavioral Sciences*, *59*, 110–116. https://doi.org/10.1016/j.sbspro.2012.09.253

Van Dyne, L., & Pierce, J. L. (2004). Psychological ownership and feelings of possession: Three field studies predicting employee attitudes and organizational citizenship behavior. *Journal of Organizational Behavior*, *25*(4), 439–459. https://doi.org/10.1002/job.249

Webb, A. L., & Choi, S. (2014). Interactive radiological anatomy eLearning solution for first year medical students: Development, integration, and impact on learning. *Anatomical Sciences Education*, *7*(5), 350–360. https://doi.org/10.1002/ase.1428

Wiggins, J. (2018). Can consumers perceive collective psychological ownership of an organization? In J. Peck & S. Shu (Eds.), *Psychological ownership and consumer behavior* (pp. 177–194). Springer, Cham. https://doi.org/10.1007/978-3-319-77158-8_11

Wilcox, P., Land, K. C., & Hunt, S. A. (2003). *Criminal circumstance: A dynamic multi-contextual criminal opportunity theory*. Taylor & Francis.

Yang, L., Su, G., & Yuan, H. (2012). Design principles of integrated information platform for emergency responses: The case of 2008 Beijing Olympic Games. *Information Systems Research*, *23*(3-part-1), 761–786. https://doi.org/10.1287/isre.1110.0387