Supplementary File S1

Instructor-Led Demonstration, Questionnaire, and Implementation Protocol for GAI-Based Agents in an E-Commerce Course

Selected textbook topic: E-commerce Business Models and Concepts, based on the textbook E-commerce: Business, Technology, Society by Kenneth C. Laudon and Carol Guercio Traver [S1].

Note: This supplementary material does not reproduce textbook content. It operationalizes a standard e-commerce topic through instructor-designed learning activities, prompts, agent roles, and assessment procedures.

S1. Purpose, survey demonstration, and relationship to the main manuscript

This supplementary file documents the instructor-led demonstration that preceded the perception questionnaire and provides a practical implementation protocol for applying generative AI-based agents in higher education, using one topic from an e-commerce textbook as a concrete teaching case. It supports the Agentic GAI-Supported Learning Framework for Higher Education (AGAI-HE) by showing how lecturers and students can configure, prompt, monitor, and evaluate GAI-agent-supported learning activities.

Before completing the questionnaire, the 130 students attended an instructor-led demonstration of three alternative approaches to solving the same problem-based e-commerce task derived from Laudon and Traver [S1]:

- Traditional e-learning without GAI;
- GAI-chatbot-supported problem solving through prompt-response interaction; and
- A prompt-based simulation of AGAI-HE functions in which GAI-agent-supported problem solving was represented through a structured, multi-step workflow.

  The problem context and intended learning objective were held constant across the three demonstrations.

The demonstrations were delivered during six scheduled class sessions at the Faculty of Economics and Social Sciences, University of Plovdiv Paisii Hilendarski, and lasted approximately 45 minutes. The approaches were presented in the same fixed order—traditional e-learning without GAI, standard GAI-chatbot-supported problem solving, and the prompt-based AGAI-HE simulation—and were not randomized or counterbalanced. The same task, presentation materials, prompts, and instructions were used across sessions. The chatbot and prompt-based AGAI-HE demonstrations used the OpenAI ChatGPT 5.5 interface. Participation was voluntary, and no incentive or course credit was provided.

Students observed the three approaches but did not individually complete three standardized experimental interventions. They completed the questionnaire after the demonstration and evaluated the demonstrated approaches on the basis of the presented examples and, where applicable, their prior experience with GAI tools. In this supplementary file, the term condition refers to a demonstrated learning approach, not to a randomized or participant-executed intervention. Accordingly, the empirical component reported in the main manuscript is a comparative, perception-based evaluation of demonstrated learning approaches, not a causal test of learning performance.

The remainder of this file documents the prompt-based simulation used for the GAI-agent-supported demonstration and expands its logic into a reusable classroom implementation protocol. No autonomous agent, persistent agent environment, Custom GPT, API-based workflow, or integrated multi-agent system was deployed in the reported perception study. The prompts, settings, and optional API/Agents SDK schema document the demonstrated logic and support future classroom implementation.

The protocol is designed for the topic "E-commerce Business Models and Concepts". This topic is suitable because it requires students to connect conceptual knowledge with practical decision-making: defining value propositions, comparing revenue models, assessing market opportunities, identifying competitive advantages, and selecting a suitable e-commerce strategy. These activities may be suitable for examining agentic support

because they require structured reasoning, evidence checking, and comparison of alternatives rather than simple factual recall.

The perception-based evaluation did not identify a statistically significant difference between ratings of the demonstrated agentic and chatbot approaches. Accordingly, this protocol documents a proposed agentic workflow for future implementation and testing; it does not establish that the workflow is superior to standard chatbot support.

S2. Selected topic and pedagogical rationale

Table S1. Topic alignment with the AGAI-HE framework.

Element	Implementation in the supplementary learning activity
Textbook topic	E-commerce Business Models and Concepts
Core concepts	Value proposition, revenue model, market opportunity, competitive environment, competitive advantage, market strategy, organizational development, and management team.
Applied task	Students analyze a proposed digital venture and compare marketplace, direct-to-consumer, and subscription or membership business models.
Why suitable for agentic GAI	The task requires multi-step reasoning, criteria selection, evidence organization, comparison of alternatives, uncertainty analysis, and justification of a final recommendation.
Connection with AGAI-HE	The activity uses a scenario-specific subset of the AGAI-HE roles: tutor, task-decomposition, content-curation, decision-support, verification, reflection, and assessment-support agents, under human lecturer orchestration.

S3. Learning objectives

In a future full classroom implementation, students who complete the agent-supported activity should be able to:

- Explain the main components of an e-commerce business model.
- Apply business-model concepts to a realistic online venture case.
- Compare alternative e-commerce models using explicit criteria.
- Use GAI agents to support, but not replace, independent reasoning.
- Verify AI-generated claims and distinguish evidence from assumption.
- Justify a final business-model recommendation in their own words.
- Disclose the material contribution of AI tools in a transparent and academically responsible manner.

S4. Recommended OpenAI implementation modes

The agent-supported activity can be demonstrated or implemented at three levels of technical complexity. Lecturers can select the level according to institutional resources, students' digital skills, and the intended degree of reproducibility.

Table S2. Alternative implementation modes for OpenAI-based GAI agents.

Implementation mode	Description	Recommended use
Mode A: Prompt-based simulation of AGAI-HE functions (instructor-led classroom demonstration)	No-code or low-code demonstration using a configured sequence of ChatGPT prompts. It makes the AGAI-HE workflow and role functions visible but does not constitute a technically implemented agent or multi-agent software system.	Reported pre-questionnaire demonstration, pilot studies, and ordinary course use. Document the prompts, model/interface, date, permitted tools, disclosure form, and assessment rubric.
Mode B: Custom GPT or course assistant	A reusable course assistant is configured with instructions, approved course files, and fixed output formats.	Lecturer uploads course materials, disables irrelevant tools, and monitors student logs.

Implementation mode	Description	Recommended use
Mode C: API / Agents SDK implementation	A developer or institutional IT team implements specialist agents with tools, sessions, handoffs, guardrails, and tracing.	Best for reproducible experiments, LMS integration, and controlled multi-agent workflows.

The pre-questionnaire presentation reported in the main manuscript followed Mode A, the prompt-based simulation of AGAI-HE functions. Students did not configure or operate an API-based multi-agent system. For a future research-oriented classroom implementation, Mode A is sufficient if the prompts, settings, model name, date of use, and permitted tools are documented. For a controlled institutional deployment, Mode C offers stronger management of the agent loop, state, tool permissions, approvals, and traces. OpenAI documentation describes agents as applications that plan, call tools, collaborate across specialists, and retain sufficient state to complete multi-step work [S2].

S5. Recommended settings and governance controls

Table S3. Recommended settings for responsible classroom implementation.

Setting/control	Recommended configuration
Model	Use the current high-reasoning OpenAI model available to the institution. Record exact model name, date, interface, and account type.
Memory	Disable persistent memory for assessment activities unless institutional policy explicitly permits it.
File upload	Enable only for approved course files: syllabus, assignment description, rubric, and permitted textbook notes.
Web search	Disabled during concept explanation; optionally enabled during evidence-gathering stage if students must cite current market information.
Connectors	Disable email, calendar, LMS, gradebook, and personal-data connectors for student activities.
Code/spreadsheet tools	Optional. Enable only for decision matrices, tables, or simple calculations; require students to inspect outputs.
Output format	Require tables, evidence registers, reasoning logs, decision matrices, and reflection notes, not only a final essay.
Human approval	Instructor approval is required for high-stakes assessment, final grading, and use of external data sources.
Disclosure	Students must submit an AI-use disclosure showing accepted, rejected, and revised AI suggestions.

S6. Agent roles and responsibilities

The main manuscript defines nine educational agent roles in Table 5. The e-commerce activity uses the scenario-specific subset shown below. Course-design and learning-analytics agents are not activated as student-facing roles in this demonstration. The lecturer orchestrator is a human governance role rather than an AI agent. In Mode A, the agent roles are represented through a labeled prompt sequence; in an API/Agents SDK workflow they may be implemented separately or combined, provided that the active role and its boundaries remain visible and auditable.

Table S4. Human orchestration and the scenario-specific subset of AGAI-HE agent roles used in the e-commerce activity.

Role	Primary user	Function
Lecturer orchestrator (human role)	Instructor	Defines learning outcomes, permitted sources and tools, checkpoints, assessment boundaries, and the rubric; retains final academic responsibility.

Role	Primary user	Function
Tutor agent	Student	Explains e-commerce business-model concepts, diagnoses misunderstandings, and gives short examples without completing the student's final answer.
Task-decomposition agent	Student	Splits the assignment into linked steps, milestones, and checkpoints and proposes an execution plan for student approval.
Content-curation agent	Student/instructor	Organizes approved course resources and external evidence; separates claims, sources, assumptions, and unresolved evidence needs.
Decision-support agent	Student	Supports alternative generation and comparison, builds a decision matrix, and highlights criteria, trade-offs, and uncertainty without selecting the final answer.
Verification agent	Student/instructor	Checks consistency, evidence traceability, unsupported claims, uncertain evidence, and possible hallucinations.
Reflection agent	Student	Prompts critique, revision, disclosure, and explanation of accepted, rejected, or modified AI suggestions.
Assessment-support agent	Instructor	Drafts low-stakes formative feedback using the instructor-defined rubric; does not assign final grades autonomously.

S7. Lecturer preparation protocol

Before class, the lecturer prepares a bounded agentic learning environment. The lecturer should not simply ask students to use AI freely. The learning task should specify where AI support is permitted, where independent work is required, and how AI use must be documented.

Table S5. Lecturer preparation protocol.

Step	Lecturer action
1. Select the topic	Use the business-model topic from the e-commerce course and define the applied case.
2. Define the assignment	Students compare marketplace, direct-to-consumer, and subscription or membership models for a digital venture.
3. Define sources	Textbook concepts and instructor-approved slides are required; web sources may be optional and must be cited.
4. Configure AI use	Use prompt pack; disable memory; restrict external tools; require logs and disclosure.
5. Prepare rubric	Assess conceptual alignment, evidence quality, comparison logic, verification, reflection, and written presentation.
6. Prepare checkpoints	Prepare checkpoints for the AI-use contract, task specification, execution plan, evidence register, candidate solution set, decision matrix, revised solution, and verified output with reflection log and AI-use disclosure.

S8. Student workflow

During the reported perception study, the instructor used a prompt-based simulation to demonstrate the canonical eight-stage AGAI-HE workflow summarized below. Respondents observed the sequence; they did not individually execute the complete workflow or submit its artifacts. Table S6 therefore documents both the demonstrated logic and a protocol for future classroom implementation. Independent work and concept clarification are retained within task interpretation, while source checking, reflection, and disclosure are integrated into the final verification stage.

Table S6. Canonical eight-stage AGAI-HE workflow represented in the instructor-led prompt-based simulation and proposed for future classroom implementation.

Workflow stage	Student and agent-supported action	Required artifact
Stage 1. Task contracting	The instructor and student confirm the learning outcome, permitted AI support, approved sources and tools, required deliverables, checkpoints, assessment boundaries, and disclosure expectations.	AI-use contract
Stage 2. Task interpretation	Before substantive AI support, the student states an initial independent position. The tutor agent may clarify the problem, constraints, stakeholders, business-model concepts, assumptions, and success criteria without choosing an answer.	Task specification
Stage 3. Decomposition and planning	The task-decomposition agent proposes linked subtasks and checkpoints. The student reviews, modifies, and approves their sequence.	Execution plan
Stage 4. Evidence organization	The content-curation agent helps organize approved concepts, external evidence, sources, assumptions, verification status, and missing information.	Evidence register
Stage 5. Alternative generation	The decision-support agent helps articulate candidate marketplace, direct-to-consumer, and subscription or membership solutions and relevant variants without ranking or selecting them.	Candidate solution set
Stage 6. Comparison and decision	The student defines and justifies criteria and any weights. The decision-support agent structures the comparison and makes trade-offs and uncertainty visible; the student records the provisional decision.	Decision matrix
Stage 7. Feedback and refinement	Verification and assessment-support functions identify unsupported claims, inconsistent criteria, missing risks, and revision needs. The student evaluates the feedback and revises the solution.	Revised solution
Stage 8. Verification and reflection	The student checks material claims and sources, explains accepted and rejected AI suggestions, discloses material AI contributions, and writes and defends the final recommendation.	Verified output with reflection log and AI-use disclosure

S9. Classroom activity: business-model selection for an online venture

Example case: EcoGlow is a proposed online store offering sustainable handmade cosmetics, including face creams, lip balms, body oils, soaps, and hair-care products. The target market includes eco-conscious consumers aged 18-45, young urban professionals, students, working women, and customers looking for handmade, local, or environmentally responsible alternatives. Students must compare three e-commerce business-model options: marketplace participation, direct-to-consumer web store, and subscription or membership model.

The demonstration illustrated the logic and form of the following eight workflow artifacts. They are proposed as student deliverables for future full classroom implementation but were not completed by or collected from the 130 survey respondents:

- AI-use contract defining the learning outcome, permitted support, approved sources and tools, checkpoints, assessment boundaries, and disclosure expectations;
- Task specification containing the student's initial independent position, problem definition, constraints, stakeholders, assumptions, criteria, and intended outcome;
- Execution plan identifying linked subtasks, sequencing, checkpoints, and student approval points;
- Evidence register distinguishing course concepts, external evidence, assumptions, verification status, and unresolved evidence needs;
- Candidate solution set describing the marketplace, direct-to-consumer, and subscription or membership alternatives and relevant variants;

- Decision matrix comparing alternatives through explicit criteria, justified weights where used, trade-offs, risk, and uncertainty;
- Revised solution showing how the student evaluated and responded to formative feedback;
- Verified output containing the student-authored final recommendation, source checks, uncertainty statement, AI-use disclosure, and reflection log.

S10. Prompt package

The prompt sequence below documents the structure of the GAI-agent-supported approach presented during the instructor-led prompt-based simulation. Respondents observed the demonstration rather than executing the complete prompt sequence themselves. For future classroom use, the prompts can be used in a structured ChatGPT workflow or adapted for a Custom GPT or API implementation. The prompts map to the eight stages in Table S6; the lecturer setup and instructor feedback prompts support governance and formative assessment across the workflow. Students who execute the prompts should submit a prompt log as process evidence.

Prompt S1. Lecturer setup and task-contracting prompt

You are an agentic learning assistant for a university course in e-commerce. Support learning; do not write the student's final assignment. Apply these eight AGAI-HE stages: task contracting; task interpretation; decomposition and planning; evidence organization; alternative generation; comparison and decision; feedback and refinement; verification and reflection. First, present an AI-use contract covering the learning outcome, permitted AI support, approved sources and tools, required deliverables, checkpoints, assessment boundaries, and disclosure rules. Require the student's initial independent position before substantive suggestions. Separate course concepts, external evidence, and assumptions; never invent citations; require verification of material claims; and ensure that the student writes and justifies the final recommendation.

Prompt S2. Task-interpretation and independent-start prompt

I am a student in an e-commerce course comparing marketplace, direct-to-consumer, and subscription or membership models for the EcoGlow sustainable cosmetics venture. Before offering substantive suggestions, ask me to state my initial independent position and preliminary criteria. Then help me prepare a task specification covering the problem, constraints, stakeholders, assumptions, success criteria, and intended output. Do not recommend a final business model.

Prompt S3. Tutor-agent concept-clarification prompt

Explain the following e-commerce business-model dimensions in simple academic language: value proposition, revenue model, market opportunity, competitive environment, competitive advantage, market strategy, organizational development, and management team. For each dimension, give one short example related to an online cosmetics venture. Do not recommend a final business model yet.

Prompt S4. Decomposition-and-planning prompt

Using the approved task specification, create an execution plan for analyzing the EcoGlow case. Include linked subtasks for criteria selection, evidence organization, alternative generation, comparison and decision, feedback and refinement, and verification and reflection. Add checkpoints where I must approve the plan, make my own decision, or verify evidence. Do not proceed until I approve or modify the proposed sequence.

Prompt S5. Evidence-organization prompt

Help me build an evidence register for the EcoGlow business-model analysis. Use the columns claim, course concept or source, evidence type, verification status, assumption, and unresolved evidence need. Distinguish approved course material, current market evidence, and assumptions. Ask me to provide a source whenever a material claim requires verification, and do not treat an unsupported statement as evidence.

Prompt S6. Alternative-generation prompt

Using the task specification and evidence register, help me generate a candidate solution set for marketplace participation, a direct-to-consumer web store, and a subscription or membership model. For each alternative, identify a plausible value proposition, revenue logic, operational requirements, evidence needs, assumptions, and meaningful variants. Do not rank the alternatives or select a final answer.

Prompt S7. Comparison-and-decision prompt

Using the candidate solution set and evidence register, create a decision matrix for marketplace, direct-to-consumer, and subscription or membership models. Include customer data control, brand control, startup complexity, revenue predictability, trust building, customer acquisition, operational requirements, scalability, and fit with sustainable handmade cosmetics. Ask me to justify the criteria and any weights. Make trade-offs, risk, and uncertainty visible, but do not choose the final answer. Record my provisional decision and rationale.

Prompt S8. Feedback-and-refinement prompt

Review my provisional analysis and decision for unsupported claims, missing evidence or criteria, inconsistent reasoning or scoring, unexamined risks, overreliance on AI, and weak connections with e-commerce business-model theory. Return a revision table with issue, why it matters, evidence required, and what I should reconsider. Ask me to revise the solution in my own words. Do not rewrite the assignment or make the final decision for me.

Prompt S9. Final-verification prompt

Check my revised solution against the task specification, evidence register, candidate solution set, criteria, and decision matrix. Identify unsupported or unverifiable claims, missing citations, unresolved contradictions, and conclusions that exceed the evidence. Require me to correct, qualify, or remove them. Produce a verification checklist, but do not certify any claim that has not been independently checked.

Prompt S10. Verification-reflection and disclosure prompt

Ask me five reflection questions covering what I decided independently, which AI suggestions I accepted, rejected, or substantially revised, which claims and sources I verified, how uncertainty affected my decision, and how AI support affected my understanding. Then help me organize a concise reflection log and AI-use disclosure without composing my substantive final recommendation.

Prompt S11. Instructor feedback prompt

Act as an assessment-support agent for formative feedback only. Use the rubric provided by the instructor. Identify strengths, weaknesses, missing evidence, and questions for improvement. Do not assign a final grade and do not replace the instructor's academic judgment.

S11. Assessment rubric

This rubric is proposed for future performance-based classroom evaluation. It was not used to grade the respondents or to generate the perception results reported in the main manuscript.

Table S7. Suggested assessment rubric.

Criterion	Description	Weight
Theoretical alignment	Correct use of e-commerce business-model concepts and dimensions.	20%
Evidence quality	Relevant evidence, clear distinction between source-based claims and assumptions, accurate citations if web sources are used.	20%
Alternative comparison	Transparent criteria, balanced comparison, treatment of trade-offs and uncertainty.	20%
Decision justification	Clear final recommendation written in the student's own words and logically connected to the evidence.	15%
Verification and reflection	Evidence of checking AI outputs, identifying limitations, and reflecting on accepted/rejected suggestions.	15%
Presentation quality	Coherent structure, academic style, appropriate tables and concise argumentation.	10%

S12. AI-use disclosure template

The following disclosure form is intended for future student implementation and was not completed by the respondents in the reported perception study.

AI-use disclosure statement
Student name: _____
Course/topic: E-commerce Business Models and Concepts
AI tool and model/interface used: _____
Date(s) of use: _____
Permitted sources/tools used: _____

1. I used AI for the following learning-support purposes:
   [ ] task contracting and interpretation
   [ ] decomposition and planning
   [ ] evidence organization
   [ ] alternative generation
   [ ] comparison and decision
   [ ] feedback and refinement
   [ ] verification and reflection
   [ ] other: _____

2. AI suggestions I accepted:
3. AI suggestions I rejected or substantially revised:
4. Claims or sources I independently verified:
5. Parts of the final assignment written entirely by me:
6. I confirm that I remain responsible for the final content, argumentation, and recommendation.
Signature/date: _____

S13. Optional API/Agents SDK implementation schema

The API/Agents SDK architecture was not implemented in the reported perception study and is included solely as a specification for possible future technical deployment. The schema implements the same scenario-specific subset identified in Table S4; course-design and learning-analytics functions remain outside this task-level configuration. For institutions that implement the activity through the OpenAI Agents SDK or similar API-based infrastructure, the following schema can serve as a design specification. OpenAI documentation states that the Agents SDK can manage the agent loop, recurring orchestration, specialist instructions, tools or policies, sessions, tracing, guardrails, and resumable approval flows [S2].

Table S8. Optional multi-agent implementation schema.

Agent	Tools	Guardrail / approval rule	Output
Tutor agent	Approved course files	May clarify concepts and task terms; may not write the final recommendation.	Task-specification clarification notes
Task-decomposition agent	Assignment file and rubric	Must obtain the student's initial position and approval before finalizing the plan.	Execution plan with checkpoints
Content-curation agent	Course files and optional web search	External claims must include a source and retrieval date; assumptions must remain labeled.	Evidence register
Decision-support agent	Spreadsheet or table tool	Must generate and compare alternatives, present trade-offs, and leave the final decision to the student.	Candidate solution set and decision matrix
Verification agent	All previous artifacts	Must flag unsupported claims, uncertain evidence, and unresolved contradictions; may not certify unchecked claims.	Verification checklist and verified-output conditions
Reflection agent	Student draft and AI-use log	Must elicit student-authored justification, reflection, and disclosure.	Reflection log and disclosure questions
Assessment-support agent	Rubric and process artifacts	May draft formative feedback; the instructor retains final assessment and grading authority.	Formative feedback for revision

S14. Risk mitigation measures

- Require an initial independent answer before AI consultation to reduce anchoring and overreliance.
- Use AI for process support, not for direct final-answer generation.
- Require evidence registers and source verification for all external claims.
- Prohibit undisclosed use of AI-generated final text.
- Use oral defense, short in-class explanation, or reflective questions when authorship is uncertain.
- Avoid uploading personal data, unpublished student work, or confidential institutional information.
- Review the settings and model version at the start of each semester because AI interfaces change quickly.

S15. Conceptual comparison of GAI-based and classical educational agents

Generative AI-based agents differ from classical software agents in several important respects. Classical agents are usually designed around predefined goals, rules, ontologies, workflows, or domain-specific knowledge bases. They may act autonomously within a limited environment, but their capacity to interpret open-ended educational tasks, generate new explanations, adapt language to the learner, and reorganize a problem in natural language is constrained by the rules and representations defined during system design. By contrast, GAI-based agents combine the goal-directed and tool-using logic of agent systems with the generative and reasoning capabilities of large language models. They can interpret ambiguous instructions, maintain task state across several steps, call external tools or approved knowledge sources, generate alternative solution paths, compare criteria, provide formative feedback, and prompt students to verify and reflect on their reasoning. In higher education, this makes them especially useful for complex learning tasks that require problem framing, evidence organization, decision support, and iterative refinement rather than only the retrieval of predefined answers.

The proposed pedagogical contribution of GAI-based agents is therefore not only automation, but structured learning orchestration. A classical agent may deliver a reminder, recommend a resource, or execute a rule-based tutoring sequence. A GAI-based educational agent can additionally support task decomposition, contextual explanation, adaptive scaffolding, comparison of alternatives, reflective questioning, and human-in-the-loop verification. This is particularly relevant in applied domains such as e-commerce, where students must connect theoretical concepts with market evidence, evaluate business model alternatives, and justify decisions under uncertainty. However, these advantages also create new risks, including overreliance, hallucinated evidence, unclear authorship, and reduced independent reasoning. For this reason, the proposed framework treats GAI-based agents as bounded and supervised educational partners whose outputs must be verified by students and validated by instructors, rather than as autonomous substitutes for academic judgment.

S16. Questionnaire Used in the Exploratory Perception-Based Evaluation

The questionnaire was administered in Bulgarian between 12 May and 9 June 2026. This section provides the English translation of the field version dated 11 May 2026. It reproduces the information and definitions supplied to respondents, the profile and prior-use questions, all attitudinal items I01–I32, the response scale, the open-ended question, and the scoring rules. The item wording is reproduced without substantive alteration.

The field questionnaire was originally developed in Bulgarian for this exploratory study and was not translated from an English-language instrument for administration. The English version was prepared by the authors after data collection for international reporting and transparency; it was not administered to respondents. No formal forward–back-translation, expert content-validation panel, content-validity indexing, cognitive interviewing, separate pilot testing, or psychometric evaluation of the English version was conducted. The reported reliability and dimensionality statistics therefore apply to the Bulgarian field instrument and should not be interpreted as validation of the English translation.

Respondent introduction and definitions

The purpose of the survey is to examine students' attitudes toward the use of generative artificial intelligence in learning.

In the context of learning, generative artificial intelligence (GAI) refers to software tools that can create new content (text, images, computer code, etc.) using pretrained models.

The questionnaire covers three different approaches to learning:

1. Traditional e-learning: Learning takes place through electronic and online learning materials, learning management systems, and e-learning platforms without the use of GAI. Examples include Moodle, Google Classroom, Microsoft Teams, online lectures, electronic learning resources, and video materials used without GAI support.

2. GAI-chatbot-supported learning: GAI-based chatbots support learning by providing rapid access to information, generating ideas, explaining learning content, and delivering feedback. Examples include ChatGPT, Copilot, Gemini, Claude, Perplexity, and others.

3. GAI-agent-supported learning: GAI agents go beyond conventional GAI-chatbot functionality by providing structured, multi-step support for solving more complex tasks, analyzing information, organizing workflows, and making decisions. Examples include Custom GPTs, AutoGPT, AgentGPT, Microsoft Copilot Agents, multi-agent AI systems with roles such as analyst, strategist, and evaluator, and AI-based workflows for developing business models and strategies and analyzing data.

For students, GAI tools can create interactive learning materials and provide personalized learning experiences through text- or voice-based interfaces.

For instructors, GAI tools can generate learning materials and assessment questions, support the creation of interactive content, and facilitate administrative activities such as planning, assessment, and feedback provision.

GAI chatbots can be accessed through platforms such as https://chat.openai.com, where ChatGPT generates answers to questions formulated in natural language. GAI agents are generally accessed through the advanced functionalities of such platforms or through specialized learning environments that support the structured, multi-step completion of assignments.

Completing the questionnaire will take approximately five minutes. Your responses are anonymous and will be used solely for scientific purposes.

Thank you for participating!

11 May 2026 — Research team of students and instructors from the Faculty of Economics and Social Sciences

Student profile and experience with GAI tools

1. Current educational level ○ Bachelor's ○ Master's

2. Major Your free-text response: _____

3. Gender ○ Woman ○ Man

4. Digital skills ○ Low level (I often need assistance) ○ Medium level (I usually manage independently) ○ High level (I experience no difficulty using information and communication technologies)

5. Have you used a GAI chatbot such as ChatGPT or a similar tool for learning? ○ Never ○ Rarely ○ Sometimes ○ Often ○ Very often

6. For which purposes do you most often use a GAI chatbot for learning? (More than one response may be selected.) ☐ Understanding concepts ☐ Summarization ☐ Academic writing ☐ Problem-solving ☐ Preparation for assessments, tests, and examinations

7. Have you used a GAI agent such as ChatGPT Agent Mode or a similar tool for learning? ○ Never ○ Rarely ○ Sometimes ○ Often ○ Very often

8. For which purposes do you most often use GAI agents for learning? (More than one response may be selected.) ☐ Solving complex assignments ☐ Decision-making ☐ Data analysis ☐ Analysis and comparison of business processes, scenarios, and strategies ☐ Preparation of written reports

Likert instruction: Rate each statement using a five-point Likert scale: 1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree.

Table S9. Exact attitudinal items used in the exploratory perception-based evaluation.

Item	Construct	Learning approach	Exact item wording	Response scale
I01	Learning Enhancement	Traditional	Traditional e-learning helps me understand the learning material.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I02	Learning Enhancement	Traditional	Traditional e-learning helps me master the learning material.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I03	Learning Enhancement	GAI chatbot	GAI chatbots help me understand the learning material.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I04	Learning Enhancement	GAI chatbot	GAI chatbots help me master the learning material.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I05	Learning Enhancement	GAI agent	GAI agents help me understand complex tasks, cases, and problem situations.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I06	Learning Enhancement	GAI agent	GAI agents help me master the learning material quickly and effectively.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I07	Personalization	Traditional	Traditional learning is fully tailored to my needs.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I08	Personalization	GAI chatbot	GAI chatbots adapt explanations to my needs.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I09	Personalization	GAI chatbot	GAI chatbots provide personalized learning support.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I10	Personalization	GAI agent	GAI agents provide useful guidance tailored to my level of preparation.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I11	Personalization	GAI agent	GAI agents help me connect theory with its practical application.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I12	Decision-Making Support	Traditional	Traditional learning helps me develop decision-making skills.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I13	Decision-Making Support	GAI chatbot	GAI chatbots help me generate ideas for solving assigned tasks.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I14	Decision-Making Support	GAI chatbot	GAI chatbots support the decision-making process.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I15	Decision-Making Support	GAI agent	GAI agents help me compare different alternatives.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree

Item	Construct	Learning approach	Exact item wording	Response scale
I16	Decision-Making Support	GAI agent	GAI agents improve my ability to justify my decisions.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I17	Workflow Support	Traditional	Traditional learning helps me organize my study preparation effectively.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I18	Workflow Support	GAI chatbot	GAI chatbots help me structure my work.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I19	Workflow Support	GAI agent	GAI agents help me organize my tasks through clear and sequential steps.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I20	Workflow Support	GAI agent	GAI agents improve the logical structure of my work.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I21	Workflow Support	GAI agent	GAI agents help me produce more complete and coherent solutions.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I22	Perceived Risk	General GAI	I may become dependent on GAI tools.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree

Table S9. (continued)

Item	Construct	Learning approach	Exact item wording	Response scale
I23	Perceived Risk	General GAI	Using GAI tools may reduce my independent and critical thinking.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I24	Perceived Risk	General GAI	It is difficult to assess the validity of results generated by GAI.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I25	Comparative Evaluation	Comparison	I learn more effectively with GAI chatbots than with traditional learning.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I26	Comparative Evaluation	Comparison	I learn more effectively with GAI agents than with GAI chatbots.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I27	Comparative Evaluation	Comparison	GAI agents provide more structured support than GAI chatbots.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I28	Comparative Evaluation	Comparison	The best results are achieved by combining the three learning approaches.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I29	Trust and Adoption	Trust/adoption	I trust GAI more when instructor guidance and supervision are provided.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree

Item	Construct	Learning approach	Exact item wording	Response scale
I30	Trust and Adoption	Trust/adoption	I would like to receive training in the effective use of GAI tools.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I31	Trust and Adoption	Trust/adoption	I intend to continue using GAI agents in my learning.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree
I32	Trust and Adoption	Trust/adoption	GAI agents should be integrated into learning.	1 = Strongly disagree; 2 = Disagree; 3 = Neither agree nor disagree; 4 = Agree; 5 = Strongly agree

Open-ended question

16. Opinions, Suggestions, and Recommendations

Please share your opinion on the role of GAI technologies in higher education, including teaching, learning, examination, and assessment. Do you have suggestions for improving the quality of the learning process? Has your attitude toward the use of GAI tools changed?

Coding and scoring rules

Table S9 also serves as the item dictionary by reporting each item code, construct, learning approach, and exact wording. The remaining coding rules are summarized in Table S10.

Table S10. Coding rules for profile, use-frequency, Likert, and multi-response variables.

Variable	Response or option	Code
DEGREE	Bachelor's / Master's	1 = Bachelor's; 2 = Master's; included in both released data files
SPECIALTY	Free-text programme/specialty	Original and harmonized programme fields included in both released data files
GENDER	Woman / Man	1 / 2
DIGITAL_SKILL	Low / Medium / High level	1 / 2 / 3
CHAT_FREQ; AGENT_FREQ	Never / Rarely / Sometimes / Often / Very often	0 / 1 / 2 / 3 / 4
I01–I32	Strongly disagree / Disagree / Neither / Agree / Strongly agree	1 / 2 / 3 / 4 / 5; blank = N/A
CHAT_CONCEPTS	Understanding concepts	0 = not selected; 1 = selected
CHAT_SUMMARY	Summarization	0 = not selected; 1 = selected
CHAT_WRITING	Academic writing	0 = not selected; 1 = selected
CHAT_PROBLEM_SOLVING	Problem-solving	0 = not selected; 1 = selected
CHAT_EXAM_PREP	Preparation for assessments	0 = not selected; 1 = selected
AGENT_COMPLEX_TASKS	Solving complex assignments	0 = not selected; 1 = selected
AGENT_DECISIONS	Decision-making	0 = not selected; 1 = selected
AGENT_DATA_ANALYSIS	Data analysis	0 = not selected; 1 = selected
AGENT_BUSINESS_ANALYSIS	Analysis and comparison of business processes, scenarios, and strategies	0 = not selected; 1 = selected
AGENT_REPORTS	Preparation of written reports	0 = not selected; 1 = selected

Table S11. Composite-scoring rules.

Score	Items	Rule
LE_Trad	I01–I02	Mean
LE_GenAI	I03–I04	Mean
LE_GAI	I05–I06	Mean
PERS_Trad	I07	Single item
PERS_GenAI	I08–I09	Mean
PERS_GAI	I10–I11	Mean
DM_Trad	I12	Single item
DM_GenAI	I13–I14	Mean
DM_GAI	I15–I16	Mean
STRUCT_Trad	I17	Single item
STRUCT_GenAI	I18	Single item
STRUCT_GAI	I19–I21	Mean
RISK	I22–I24	Mean; higher = more risk
COMPARATIVE	I25–I28	Mean
TRUST_ADOPTION	I29–I32	Mean
AGENT_SUPPORT_GENERAL	I05, I06, I10, I11, I15, I16, I19–I21	Mean of nine agent-support items
OPS_Trad	LE_Trad, PERS_Trad, DM_Trad, STRUCT_Trad	Equal-weight mean of the four domain scores
OPS_GenAI	LE_GenAI, PERS_GenAI, DM_GenAI, STRUCT_GenAI	Equal-weight mean of the four domain scores
OPS_AGAI	LE_GAI, PERS_GAI, DM_GAI, STRUCT_GAI	Equal-weight mean of the four domain scores

No Likert item was reverse-coded. Higher perceived-risk scores indicate greater concern. Cronbach's alpha was calculated only for multi-item composites and is not applicable to single-item measures. The three OPS scores are equal-weight means of the four domain scores and are used for the principal cross-condition comparison. The nine-item AGENT_SUPPORT_GENERAL score summarizes the common factor among the AGAI-HE items and should not be confused with OPS_AGAI.

For future datasets, a composite should be set to missing when its required items are missing unless a prespecified minimum-valid-item rule is adopted before analysis. In the supplied dataset, all component items are complete.

The questionnaire measures perceived learning support, personalization, decision support, workflow organization, risk, trust, and adoption. The nine AGAI-HE support items primarily reflected one dominant general perceived-support factor; the four domain scores are therefore descriptive, strongly overlapping facets rather than independent empirical confirmations. The instrument does not measure objective performance or establish causal learning effects.

S17. Companion Questionnaire and Anonymous Data Files in Mendeley Data

Three companion files deposited in Mendeley Data [S3] support the exploratory, perception-based evaluation reported in Section 5 of the main manuscript. They complement this implementation protocol and do not contain objective learning-performance outcomes, instructor or expert appraisals, or records of participant-executed experimental interventions.

AGAI_HE_Anonymous_Collected_Submissions_131.ods

This file preserves the 131 anonymous submissions collected during the field period. It contains the original Bulgarian survey responses and a standardized coded-data sheet. Duplicate response R106 is retained and explicitly flagged for documentation but must not be used in analysis.

AGAI_HE_Anonymous_Analytical_Data_130.ods

This file contains the 130 unique analytical records after exclusion of duplicate R106, with original source identifiers retained. It includes timestamp, educational level, major, profile and prior-use variables, items I01–

I32, the original Bulgarian and English-translated open comments, 16 primary and general derived scores, the three equal-weight OPS scores, and the response-level sentiment-analysis audit fields. Results reports the principal OPS comparison, Holm-adjusted pairwise tests and rank-biserial effect sizes, reliability and dimensionality checks, the reported Spearman correlations, and sentiment summaries. Quality_Checks documents record and result reconciliation.

Agentic_Questionnaire_with_Coding_Rules_130_Revised.odt

This file provides the English translation of the Bulgarian questionnaire administered in May–June 2026 and its coding manual. The translation was prepared after data collection for reporting and was not formally forward–back-translated or psychometrically evaluated. The file includes the respondent introduction; profile and prior-use questions; items I01–I32; the open-ended question; coding rules; the item dictionary; formulas for all derived and OPS scores; sentiment-analysis documentation; missing-data rules; specialty harmonization; and interpretation boundaries.

S18. Instructor and Expert Appraisal Protocol for Future Evaluation

The following protocol is proposed for future evaluation and was not administered in the present study. Instructors and relevant experts may rate each criterion on a five-point scale (1 = wholly inadequate; 5 = fully adequate) and provide an open comment. The appraisal should report reviewer number and expertise, recruitment and independence, materials reviewed, individual or aggregated ratings, qualitative comments, resulting revisions, consent procedures, and limitations.

Table S12. Proposed instructor and expert appraisal protocol for future evaluation.

Criterion	Appraisal question	Response
1. Workflow clarity	Are the purpose, sequence, outputs, and decision points of all eight stages clear and complete?	1–5; comment
2. Learning-outcome alignment	Does the workflow align with intended course learning outcomes without displacing essential student reasoning?	1–5; comment
3. Time feasibility	Can the workflow be completed within available teaching and student-working time?	1–5; comment
4. Instructor workload	Are preparation, monitoring, checkpoint, feedback, and assessment demands sustainable?	1–5; comment
5. Assessment compatibility	Are the artifacts and rubric compatible with existing assessment procedures and standards?	1–5; comment
6. Human approval	Are the proposed instructor and student checkpoints adequate for consequential decisions?	1–5; comment
7. Student autonomy	Do the boundaries and responsibilities preserve student ownership, productive effort, and final judgment?	1–5; comment
8. Evidence verification	Are source-traceability, claim-checking, uncertainty, and correction requirements adequate and workable?	1–5; comment
9. Academic integrity	Are authorship, disclosure, permitted-use, and misconduct safeguards sufficiently clear?	1–5; comment
10. Privacy and governance	Are data minimization, tool permissions, institutional policy, and accountability requirements adequate?	1–5; comment

Any resulting exercise should be described as a preliminary instructor feasibility appraisal, not expert validation. It would address perceived feasibility only and would not demonstrate learning effectiveness, validate the student findings, or establish agentic superiority.

Supplementary references

S1. Laudon, K.C.; Traver, C.G. E-Commerce 2023–2024: Business, Technology, Society, 18th Global ed.; Pearson: Harlow, UK, 2024.

S2. OpenAI. Agents SDK. Available online: https://platform.openai.com/docs/guides/agents (accessed on 15 July 2026).

S3. Ilieva, G.; Yankova, T.; Ruseva, M.; Klisarova-Belcheva, S.; Georgiev, P.; Totkov, G. Students' Attitudes towards the Use of Generative Artificial Intelligence in Higher Education Learning. Mendeley Data 2026, V1. https://doi.org/10.17632/5w6vr73tc8.1