## **Online Appendix of**

# **Generative AI Usage and Academic Performance**

Variables	Definition	Rationale	Reference
Exam Score	Continuous measure of student performance in the final exam of the mandatory introductory accounting course indicating the percentage of points a student achieved in the final exam. The minimum is zero and the actual (achievable) maximum is 96.67 (100).	solve course-relevant problems, therefore approximating student performance.	citation 4, Cheng and Ding (2021), Eskew and Faley (1988), Hu et al.
GenAI User	Indicator variable depicting student usage of GenAI applications for studying and crafting work that they intentionally should have written on their own. <i>GenAI User</i> is estimated by ZeroGPT, a GenAI detection system indicating the percentage of text identified as created by GenAI applications. <i>GenAI User</i> equals one if the estimate of ZeroGPT exceeds a threshold of 0.5 and is zero otherwise. In our robustness checks we use alternating thresholds of the ZeroGPT estimation (i.e., 0.4 and 0.6) to distinguish GenAI users from non-users.	(e.g., simplification of complex topics and personalized learning) as well as negative effects (e.g., risk of superficial understanding and loss of independent problem-solving) of using GenAI applications in higher education. These factors can either enhance or impede	et al. (2023), Gilson et al. (2023), AlAfnan et al. (2023), Pavlik (2023), Engelmann et al. (2023), Calderon et al. (2023), Sallam et al. (2023), Qadir (2023), Lund et al. (2023), Wu et al. (2023), Perkins (2023), Cotton et al. (2023), Ali et al. (2023), Sullivan et al. (2023) Negative effects of GenAI usage: Markauskaite et al. (2022), Eager and Brunton (2023), Jain and Kapoor (2013), Rasul et al. (2023), Crawford et al. (2023a), Sallam et al. (2023), Crawford et al. (2023b), Lund et al. (2023), Milano et al. (2023), Bangert- Drowns et al. (2004),

Variables	Definition	Rationale	Reference
A-Level Grade	Continuous measure school performance prior to entering university, ranging from 4.0 (best grade) to 1.0 (worst grade).		Azzali et al. (2023), Eskew and Faley (1988), Lento (2018), Massoudi et al.
Attempt	Continuous measure equals the number of times a student has registered for the final exam with a maximum value of five, as student must pass the examination within five semesters (i.e. five attempts) according to the regular examination regulations.	number of attempts) affect performance. We include <i>Attempt</i> into our analyses to	author self-citation 2, Dowling et al.
Attendance	Continuous measure indicating the number of tutorials a given student attended scaled by the total number of tutorials offered to the students. Information on students' attendance was collected by conducting short in-class quizzes on the LMS comprising three questions regarding the specific tutorial contents in each tutorial. To participate in the quizzes, the students had to sign in to the LMS utilizing a QR-code presented to them in the corresponding tutorial.	association between student behavior (e.g., attendance) and their exam performance. The students' attendance reflects their effort and motivation they spend on the given course Byrne and Flood (2008). We therefore include	author self-citation 2, Aldamen et al. (2015), Cheng and Ding (2021),
Vocational Training	Indicator variable equal to one if a given student completed vocational training before entering university, and zero otherwise.	•	author self-citation 1, Guney (2009),
Voluntary Service	Indicator variable equal to one if a student completed a voluntary service or spent a gap year prior to entering university, and zero otherwise.		author self-citation 1, Guney (2009),

Variables	Definition	Rationale	Reference
		Service to control for this potential impact.	
Female	Indicator variable equal to one if a student is female, and zero otherwise.	Related studies provide evidence for students' gender affecting their exam performance. The results of these studies are versatile, indicating a positive, negative, or no effect of gender on performance. We control for a potential influence by integrating <i>Female</i> into our analyses.	<ul> <li>author self-citation 3, Aldamen et al. (2015), Gammie et al. (2003), Gracia and Jenkins (2003), Mutchier et al. (1987), Premuroso et al. (2011), Tan and Laswad (2008), Tyson (1989)</li> <li>Negative effect on exam performance: Johansson et al. (2022), Koh and Koh (1999), Massoudi et al. (2017), Tan and Laswad (2008)</li> <li>No significant effect on exam performance: Azzali et al. (2023),</li> </ul>
			Byrne and Flood (2008), Hu et al. (2023), Papageorgiou and Halabi (2014)
LinkedIn User	Indicator variable equal to one if a student has a LinkedIn profile, and zero otherwise.	Having a LinkedIn profile potentially impacts exam performance and is therefore included in our analyses. Related studies document LinkedIn usage being correlated with exam performance. Moreover, (new) social media usage (e.g., LinkedIn usage) can be utilized as operationalization for personal innovativeness, which in turn affects GenAI acceptance among students.	Study documenting an effect on exam performance: Paul et al. (2012) Study documenting an effect on personal innovativeness: Strzelecki (2023) Studies documenting an effect on social media usage: Aldahdouh et al. (2020), Wijesundara and Sun (2018)
Course of Study	Categorial variable equal to one if a given student is registered for business studies, two for economics, three for economics in complementary subject, four for engineering and management - production engineering, five for electrical engineering with management, six for information systems and management, and seven for others, respectively. We integrate Course of Study as fixed effects in our analyses.	across different courses of study as each attract certain student sub-populations. We consider that this potentially influences students' exam performance and therefore include Course of Study	exam performance: Cheng and Ding (2021), Duff (2004), Jackson and Cossitt (2015), Tan and Laswad

Variables	Definition	Rationale	Reference
German Detector	Indicator variable alternatively deployed as <i>GenAI User</i> estimated by the detection system developed at the University of Applied Sciences Wedel. <i>German Detector</i> equals one if the estimate of Originality.AI exceeds a threshold of 0.1 and is zero otherwise.	GenAI User are characterized by the morphological and semantic peculiarities	Tlok et al. (2023)
Originality.AI	Indicator variable alternatively deployed as <i>GenAI User</i> estimated by the detection system Originality.AI. <i>Originality.AI</i> equals one if the estimate of Originality.AI exceeds a threshold of 0.5 and is zero otherwise.	by using alternative detection tools. We	Walters (2023)
Manual Computation	Continuous measure indicating GenAI application usage for text generation. <i>Manual Computation</i> is extracted from principal component analysis comprising <i>Adjectives</i> , <i>Fog Index</i> , and <i>Herdan's C</i> . We use this GenAI detection as an alternative estimation of <i>GenAI</i> <i>User</i> in our robustness checks.	alternative measure to estimate <i>GenAI</i> <i>User</i> to test the robustness of our main analysis. Systems detecting GenAI	Markowitz et al. (2023), Martínez et al. (2024), Muñoz-Ortiz et al. (2023), Shah et al. (2023), Deveci et al. (2023),
Adjectives	Continuous measure indicating the number of adjectives scaled by the total number of words of a text.	We regard <i>Adjectives</i> as a determinant for GenAI usage to create texts and include it into the principal component analysis to extract <i>Manual Computation</i> . Related studied characterize GenAI texts to encompass more adjectives. By scaling the absolute number of adjectives by the total number of words of a given text, we avoid a biased measure due to the text length.	Markowitz et al. (2023)

Variables	Definition	Rationale	Reference
Fog Index	Gunning (1952) readability index, calculated as: $\left(\frac{Total Words}{Total Sentences} + 100 * \frac{n_{wsy\geq3}}{Total Words}\right) * 0.4$ where $n_{wsy} \geq 3$ is the number of words with three syllables or more. A higher (lower) Fog Index indicates an easier (a more difficult) read.		Gunning (1952)
Herdan's C	Herdan (1960) lexical richness index, calculated as: log (Total Unique Terms) log (Total Words)	<i>Herdan's C</i> is included into the principal component analysis to extract Detection Factor. Related studies provide evidence on lexical richness to be predictive for the use of GenAI applications to generate texts. We deploy <i>Herdan's C</i> to approximate lexical diversity and richness.	Herdan (1960)

Appendix A. Variable Definitions.

Panel A: Student Data	Ν	Mean	Мес	lian	SD	P25	P75
Exam Score	193	45.39	45.83		22.23	27.50	61.11
GenAI User	193	0.306			0.462		
ZeroGPT	193	0.354	0.296		0.277	0.119	0.556
A-Level Grade	193	2.290	2.200		0.607	1.800	2.700
Attempt	193	1.425	1		1.223	1	1
Attendance (relative)	193	0.447	0.444		0.322	0.111	0.778
Vocational Training	193	0.135			0.342		
Voluntary Service	193	0.363			0.482		
Female	193	0.472			0.500		
LinkedIn User	193	0.192			0.395		
Panel B: Student Data by GenAI Usage		GenAI	User		Non-User		/Diff./
Variables		Ν	Mean	N	Mean		
Exam Score		59	39.120	134	48.147		9.027 ***
A-Level Grade		59	2.184	134	2.337		0.152 *
Attempt		59	1.763	134	1.276		0.486 **
Attendance (relative)		59	0.413	134	0.463		0.051
Vocational Training		59	0.085	134	0.157		0.072
Voluntary Service		59	0.322	134	0.381		0.059
Female		59	0.390	134	0.508		0.118
LinkedIn User		59	0.221	134	0.179		0.041

Table 1 presents the descriptive statistics of student characteristics in Panel A. For binary variables, only means and standard deviations are presented. Panel B shows student characteristics disaggregated by GenAI usage. The last column presents the difference in mean values and the significance level of a two-tailed *t*-test (chi-squared test) for continuous (binary) variables. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Appendix B. Descriptive Statistics

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	VIF
(1) GenAI User	1.000								1.13
(2) A-Level Grade	-0.116 *	1.000							1.16
(3) Attempt	0.184 **	-0.152 **	1.000						1.19
(4) Attendance	-0.072	0.214 ***	-0.331 ***	1.000					1.29
(5) Vocational Training	-0.097	0.014	-0.100	0.049	1.000				1.20
(6) Voluntary Service	-0.056	0.057	-0.051	-0.066	-0.298 ***	1.000			1.16
(7) Female	-0.109	0.041	0.003	-0.001	-0.038	0.173 **	1.000		1.18
(8) LinkedIn User	0.048	0.106	0.057	-0.059	-0.038	0.071	0.067	1.000	1.05

Appendix B presents the pairwise pearson correlations of the variable of interest *GenAI User* and the control variables. \*\*\*, \*\*, and \* indicate statistical significance at 1%, 5%, and 10% level, respectively. The last column depicts the Variance Inflation Factor (VIF). The mean VIF is 1.17. All variables are defined in Appendix A.

Appendix C. Pearson Correlations.	Appendix C.	Pearson Correlations
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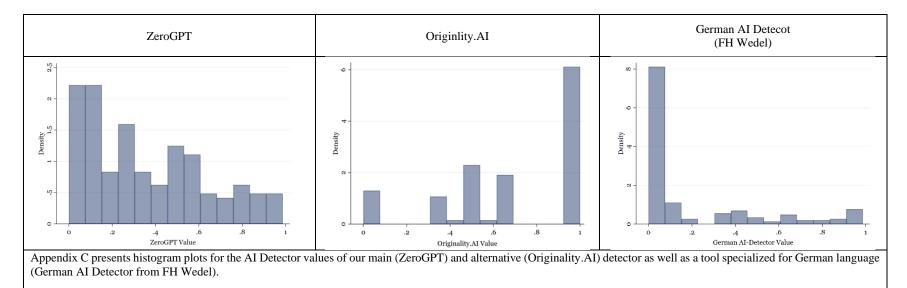
	(1)	(2)	(3)	(4)	(5)	(6)
	Threshold 0.4	Threshold 0.6	Originality.AI	German	Manual	Balanced
Variables				Detector	Computation	Sample
GenAI User	-7.10 **	-7.17 **	-4.14	-8.53 ***	-2.66 ***	-6.51 **
	(-2.43)	(-2.02)	(-1.38)	(-2.90)	(-2.70)	(-2.07)
A-Level Grade	11.64 ***	11.42 ***	11.42 ***	11.21 ***	11.62 ***	8.88 ***
	(4.92)	(4.78)	(4.73)	(4.75)	(4.87)	(3.03)
Attempt	0.89	0.84	0.29	0.94	0.79	2.05 **
•	(0.74)	(0.69)	(0.24)	(0.79)	(0.66)	(1.98)
Attendance (relative)	17.70 ***	18.38 ***	18.01 ***	16.81 ***	15.55 ***	17.75 ***
	(3.75)	(3.87)	(3.78)	(3.58)	(3.25)	(2.95)
Vocational Training	10.37 **	11.25 ***	11.98 ***	10.93 **	12.09 ***	8.75
-	(2.41)	(2.63)	(2.79)	(2.58)	(2.86)	(1.65)
Voluntary Service	1.81	2.07	2.13	1.57	1.24	1.52
	(0.60)	(0.69)	(0.71)	(0.53)	(0.41)	(0.45)
Female	-10.14 ***	-9.29 ***	-9.97 ***	-10.20 ***	-10.18 ***	-10.49 ***
	(-3.50)	(-3.18)	(-3.41)	(-3.54)	(-3.50)	(-3.22)
LinkedIn User	10.75 ***	9.25 ***	9.05 **	10.26 ***	7.89 **	10.53 ***
	(3.05)	(2.65)	(2.58)	(2.96)	(2.25)	(2.82)
Constant	Included	Included	Included	Included	Included	Included
Course of Study-FE	Included	Included	Included	Included	Included	Included
N	193	193	193	193	193	193
Adj. R <sup>2</sup>	0.31	0.30	0.29	0.32	0.31	0.20

Table 3 presents the results of the robustness checks. In columns (1) and (2), we reduced (> 0.4) or increased (> 0.6) the threshold of the AI detector value to be classified in the *GenAI User* group. Columns (3) and (4) use alternative AI detectors. Column (5) includes a manual computed score that represents AI detection. In column (6), we again present our main results but with an entropy-balanced sample. Bold font indicates the variable of interest. \*\*\*, \*\*, \* indicate statistical significance at the 1%, 5%, and 10% level (two-tailed), respectively. *t*-values are presented in parentheses. All variables are defined in Appendix A (https://tinyurl.com/zjehfa3n).

Appendix D. Results of Robustness Checks

Students' GenAI usage	Ν	Yes	No
GenAI usage for general purposes within the course	30	8 (0.267)	22 (0.734)
GenAI usage for academic essay-writing within the course	30	9 (0.300)	21 (0.700)

Appendix E. Survey Results.



Appendix F. Distribution of AI Detector

#### German Version

#### Geben Sie die ersten sechs Ziffern Ihrer Matrikelnummer an.

Tragen Sie hierfür Ihre Matrikelnummer in das vorgesehene Antwortfeld ein. (Eingabebeispiel: 123456)

#### Welchen Studiengang belegen Sie?

Tragen Sie hierfür die Ziffer Ihres Studiengangs in das vorgesehene Antwortfeld ein.

- Betriebswirtschaftslehre: "1"
- Wirtschaftswissenschaft (Vollfach): "2"
- Wirtschaftswissenschaft (Komplementärfach): "3"
- Wirtschaftsingenieurwesen Produktionstechnik: "4"
- Wirtschaftsingenieurwesen Elektrotechnik/Informationstechnik: "5"
- Wirtschaftsinformatik: "6"
- Sonstiges: "7"

#### (Eingabebeispiel: 1)

#### Geben Sie Ihr Geschlecht an.

Tragen Sie hierfür "männlich", "weiblich" oder "divers" in das vorgesehene Antwortfeld ein. (Eingabebeispiel: weiblich)

Geben Sie Ihre Abiturnote an.

Tragen Sie hierfür Ihre Abiturnote in das vorgesehene Antwortfeld ein. (Eingabebeispiel: 2,3)

Beginnen Sie das Studium im direkten Anschluss an Ihre Schulbildung?

Tragen Sie hierfür "ja" oder "nein" in das vorgeschene Antwortfeld ein. Sofern Sie nach Ihrem Schulabschluss ein Work-and-Travel-Jahr oder ein FSJ/BFD verbracht haben, tragen Sie "nein" ein. (Eingabebeispiel: nein)

Haben Sie vor dem Beginn Ihres Studiums bereits eine Ausbildung absolviert?

Tragen Sie hierfür "ja" oder "nein" in das vorgesehene Antwortfeld ein. (Eingabebeispiel: nein)

( <b>p</b>	example: 123456)
What	course of study are you taking?
	this, enter the number of your course of study in the answer field provided.
•	Business Studies: "1"
•	
•	
•	
:	
:	Other: "7"
<i>(</i> <b>1</b>	example: 1)
(Input	(Annipit, 2)
Please To do (Input Please	e indicate your gender. this, enter "male", "female" or "diverse" in the answer field provided. example: female) e indicate your Abitur grade.
Pleaso To do (Input Pleaso To do	e indicate your gender. this, enter "male", "female" or "diverse" in the answer field provided. example: female)

**English Version** 

Did you already complete a vocational training before starting your studies?

To do this, enter "yes" or "no" in the answer field provided. (Input example: no)

Appendix G Questionnaire for Data Gathering

### **English Version:**

"Dear students, ladies and gentlemen,

As announced in the preliminary course, we would like to further improve our teaching offer in the course "Accounting & Financial Statements". Therefore, the teaching content and methods used are the subject of current research in the field of accounting education. In particular, we want to investigate how the use of artificial intelligence (AI) affects your learning success. For these research purposes, personal data is required, which will only be used in pseudonymized form. We would like to take this opportunity to ask you to complete the following questionnaire. Please note that you must be logged in to Stud.IP to do so. You can find the questionnaire at: https://elearning.unibremen.de/dispatch.php/questionnaire/answer/b283ac8dec800c39b16fa0c845f67e1f.

Our research aims to strengthen beneficial content and methods to enable you to learn better. Previous publications can be found on our homepage.

For data protection regulations, please refer to the attached privacy policy.

Thank you for your cooperation!"

## German version:

"Liebe Studierende, sehr geehrte Damen und Herren,

wie im Vorkurs angekündigt, möchten wir unser Lehrangebot in der Veranstaltung "Rechnungswesen & Abschluss" weiter verbessern. Daher sind die genutzten Lehrinhalte und -methoden Gegenstand aktueller Forschung im Bereich Accounting Education. Insbesondere soll untersucht werden, wie sich der Einsatz von künstlicher Intelligenz (KI) auf Ihren Lernerfolg auswirkt. Für diese Forschungszwecke werden personenbezogene Daten benötigt, die ausschließlich in pseudonymisierter Form verwendet werden. Wir möchten Sie an dieser Stelle bitten, den nachfolgenden Fragebogen zu bearbeiten. Beachten Sie, dass Sie hierfür auf Stud.IP eingeloggt sein müssen. Den Fragebogen finden Sie unter: https://elearning.uni-bremen.de/dispatch.php/questionnaire/answer/b283ac8dec800c39b16fa0c845f67e1f.

Durch unsere Forschung sollen vorteilhafte Inhalte und Methoden gestärkt werden, um Ihnen ein besseres Lernen zu ermöglichen. Bisherige Publikationen finden Sie auf unserer Homepage.

Die datenschutzrechtlichen Bestimmungen entnehmen Sie bitte der beigefügten Datenschutzerklärung.

Vielen Dank für Ihre Mitarbeit!"

**Appendix H Information Letter** 



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#### Informationen zum Datenschutz

Die Teilnahme an der Umfrage ist freiwillig. Durch eine Nicht-Teilnahme oder unvollständige Teilnahme entstehen keine Nachteile.

Die Erhebung und Verarbeitung personenbezogener Daten erfolgt auf Basis Ihrer Einwilligung ausschließlich zur Durchführung der Studie und zu Forschungszwecken.

Ihre im Rahmen der Studie angegebenen persönlichen Informationen werden getrennt von Ihren Antworten aus der Befragung gespeichert. Die Speicherung der Daten erfolgt <u>pseudo-nymisiert</u> über einen Code.

"Pseudonymisieren" ist nach Art. 4 der DSGVO "die Verarbeitung personenbezogener Daten in einer Weise, dass die personenbezogenen Daten ohne Hinzuziehung zusätzlicher Informationen nicht mehr einer spezifischen betroffenen Person zugeordnet werden können, sofern diese zusätzlichen Informationen gesondert aufbewahrt werden und technischen und organisatorischen Maßnahmen unterliegen, die gewährleisten, dass die personenbezogenen Daten nicht einer identifizierten oder identifizierbaren natürlichen Person zugewiesen werden".

Die pseudonymisierten Daten sind nur den an der Studie beteiligten Forschenden der Universität Bremen (FB Wirtschaftswissenschaft, Lehrstuhl für ABWL, Unternehmensrechnung und Controlling, Max-von-Laue-Straße 1, 28359 Bremen) zugänglich. Alle Personen, die Kontakt mit den Daten haben werden auf die Wahrung der Vertraulichkeit und zur Beachtung des Datenschutzes und entsprechender Geheimhaltung verpflichtet. Die personenbezogenen Daten werden zu keinem Zeitpunkt an Dritte oder in Drittländer außerhalb der EU weitergegeben.

Es findet keine automatisierte Entscheidungsfindung auf Basis der personenbezogenen Daten statt, die den Betroffenen gegenüber eine rechtliche Wirkung entfalten oder sie in ähnlicher Weise beeinträchtigen.

Die Universität Bremen hat eine Datenschutzbeauftragte bestellt. Die Datenschutzbeauftragte ist zu erreichen: Petra Banik, Justiziarin der Universität Bremen, Leiterin der Rechtsstelle, Datenschutzbeauftragte, Hochschulrecht, Satzungen und Ordnungen, Referat 06 - Rechtsstelle, VWG 2250, 29359 Bremen, Tel.: +49-421-218-60211, E-Mail: petra.banik@vw.uni-bremen.de.

Die zuständige Aufsichtsbehörde ist die Landesbeauftragte für Datenschutz und Informationsfreiheit Bremen (Arndtstraße 1, 27570 Bremerhaven).

Ihre personenbezogenen Daten werden ausschließlich zur Dokumentation der Forschung verwendet und nach Entfall des Zwecks gelöscht. Sie können außerdem jederzeit die Löschung Ihrer personenbezogenen Daten verlangen.

Im Rahmen gesetzlichen Vorgaben bestehen für von der Verarbeitung personenbezogener Daten Betroffene eine Reihe von Rechten, unter anderem Recht auf Auskunft (Art. 15 DSGVO), Recht auf Berichtigung (Art. 16 DSGVO), Recht auf Einschränkung der Verarbeitung (Art. 18 DSGVO), Recht auf Löschung ("Recht auf Vergessenwerden"; Art. 17 DSGVO), Recht auf Widerspruch (Art. 21 DSGVO), Recht auf Beschwerde bei einer Aufsichtsbehörde (Art. 13 DSGVO), Recht auf Datenübertragbarkeit (Art. 20 DSGVO).

Die Einwilligung zur Verarbeitung der personenbezogenen Daten können Sie jederzeit mit Wirkung für die Zukunft widerrufen.

**Appendix I Data Protection Statement** 

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