The Learning Office Approach to Modern 21st Century Education: Third Evaluation of a Self-Driven Concept for Student-Centered Engineering Education

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***Abstract*—This Research to Practice Full Paper presents the results of the third evaluation of the learning office approach, an alternative, self-driven branch introduced at the information technology department of an Austrian higher vocational upper secondary school encompassing grades 9 to 13 (K9–13). Learning office students benefit from a flexible class schedule, which allows them to choose time and depth for most school subjects and helps students develop valuable 21^{st} century skills.**

The results revealed a highly significantly lower variance of the grade point average in the learning office at grade 12 and a ratio of sample variances of 3.534. Expert interviews held with ten teachers showed that the most mentioned advantages of the learning office approach were an improved self-reliance of the students, enabling individualization, and supporting weaker students. Furthermore, the teachers rated the learning office as the most promising approach of a set of 14 selected methods of learning. A course evaluation conducted with one learning office cohort showed that the structure of the chosen learning office subject was rated significantly better than the structure of the selected traditional subject. Finally, students of the learning office revealed a significantly lower number of absent lab days at grade 12 and a significant correlation between absent lab days and the grade point average was discovered. The findings confirm the learning office as viable approach to 21^{st} century education.

***Index Terms*—learning office, 21^{st} century skills, student-centered learning, computer science education, person-centered approach**

I. Introduction

Student-centered approaches and self-directed learning have been found connected with several positive effects, including fewer days of absence, improved creativity, higher academic achievement and levels of thinking, fewer disciplinary problems, as well as a positive contribution to 21^{st} century skills [1]–[3]. However, most educational institutions predominantly rely on traditional teacher-centered ways of instruction. The prevailing focus on subject-specific competences seldom leaves room for actively fostering 21^{st} century skills, which are essential for modern work life. Yet, it should be the highest goal of an educational facility to prepare graduates for the future, which includes their prospective professional life.

This paper introduces an approach to modern 21^{st} century education called "learning office" and presents the results of recent analyses. After a brief review of previous work [4]–[8], the learning outcomes of students taught in the new approach are compared to students' outcomes of the traditional approach. Furthermore, the results of expert interviews with ten teachers are outlined to capture educators' opinions on the learning office project, and the course feedback of a learning office subject is compared to the feedback of a traditional subject to further investigate students' perception of the learning office. Finally, an evaluation of students' absence days is performed and presented.

II. Background

A. 21^{st} Century Learning

As a result of digitization and the transformation from an industrial age to a digital knowledge-based age, the skills needed to succeed in professional life have changed tremendously over the past decades [7] – not only for individuals, but also for a company as a whole. Therefore, educational institutions should consider these new requirements the future workforce is going to face, as suggested by Trilling and Fadel [9].

There are multiple definitions and concepts which relate to the personal and social competences needed in the modern digital era. Van Laar et al. [10] conducted a systematic review of the literature in the field of 21^{st} century and digital skills, analyzing a total of 75 studies. They integrated various

models and definitions into their "21^{st}-century digital skills" framework, which distinguishes between seven core skills and five contextual skills. The core skills build the basis to perform certain tasks and include "technical, information management, communication, collaboration, creativity, critical thinking and problem solving" [10] skills. The contextual skills help utilize core skills and encompass "ethical awareness, cultural awareness, flexibility, self-direction and lifelong learning" [10].

While the theory behind the required skills is rather clear and well-established [3], [9]–[11], the practical implementation on the side of educational institutions seems to be in substantial need of improvement. Besides a lacking integration of these competences in the curriculum, teachers have been reported to be insufficiently prepared and an overall strategy to adopt respective practices of teaching and learning is often missing [12]. Hence, reports of a gap between the competences taught at educational facilities and the skills required in the business sector can be found in the literature [13]–[15].

Van Laar et al. constructed a self-report instrument to measure 21^{st}-century digital skills and conducted a large-scale study in the working sector [3], [11]. They investigated the relationships of several attributes with 21^{st}-century digital skills and found that educational attainment is only connected to creativity in the case of self-employed workers, but no significant links with the other nine skills could be observed. This result is in accordance with the work of Sin and Neave [15], who analyzed the literature about the European Bologna Process. They found that employers did not see a strong connection between academic achievement and employability.

However, van Laar et al. found significant positive correlations between self-directed learning and the skills information management, information evaluation, communication expressiveness, collaboration, and problem solving [3]. Self-directed learning is a central concept of student-centered learning, which is believed to foster 21^{st} century skills [2], [7], [8]. The principles of student-centered education are based on the work of Carl Rogers, the inventor of client-centered therapy and person-centered learning [1], [16]. Rogers suggested to rather rely on the process of learning than on teaching static knowledge as a goal for an educational institution almost 40 years ago [1]. Freiberg built on Rogers' work and shared a similar view on modern education, criticizing that schools neglect to foster non-cognitive competences, although the business sector had realized the importance of these skills long ago [17]. The learning office is a student-centered, self-directed approach to modern education which actively fosters 21^{st} century skills [7], [8].

B. The Learning Office Approach

The term "learning office" is derived from its German name "Lernbüro", which is a didactical concept developed by Margret Rasfeld [18], [19]. She introduced the concept at the Evangelical School Berlin Centre. Her concept encompasses general knowledge subjects at the grades 7–10. Based on her approach, the learning office was extended to computing education at higher grades and implemented at the IT department of a European higher vocational upper secondary school and researched since its introduction in 2016 [4]–[8].

TABLE I
LEARNING OFFICE COURSE SCHEDULE EXAMPLE AT 11^{th} GRADE [8]

Day	Lesson									
	1	2	3	4	5	6	7	8	9	10
Mon										
Tu	TS	TS	TS	TS	TS	TS				
Wed			TS	TS	TS	TS				
Th	GK	GK	GK	GK						
Fri	GK	GK	GK	GK		TS	TS	TS	TS	

Students and their parents may select the learning office or traditional approach when they register for school at the IT department; this decision can only be changed in exceptional cases due to the high administrative effort. Learning office cohorts have a flexible class schedule allowing students to freely decide in which of the available subjects they want to progress each day by visiting the respective room ("learning office") to study self-explanatory course material and solve given exercises [6]–[8]. The structure and organization of the provided material is essential, as suggested in the principles of learning by Hattie and Yates [20]. An exemplary course schedule of learning office students at grade 11 can be seen in Table I. While students may choose between technical courses during technical subject (TS) hours, they are able to visit one of the general knowledge (GK) subjects during GK lessons. Peer learning between multiple grades is promoted as students of different grades may have learning office lessons at the same time in the same room. Some subjects, such as gymnastics, are held in the traditional way at fixed times, displayed as empty cells in the exemplary class schedule. The combination of teacher-centered and student-centered approaches is in accordance with the work of Case, who suggested to integrate the advantages of both paradigms into a third approach [21].

The learning office approach shares numerous commonalities with other educational trends, theories, and student-centered ways of learning [6], [8], like the constructivist theory [22], flipped classrooms [23], and project-based as well as problem-based learning [24]. However, the combination of self-directed learning in attendance, the partial abolition of traditional class schedules, and the flexibility of choice allowing for individualization and differentiation are unique to this approach. Since learning office students are completely self-responsible for their own learning progress [6]–[8], they are constantly required to plan, reflect, and adjust to achieve their individual learning goals. Thus, acquiring self-competence and 21^{st} century skills is a must to succeed in this approach.

Previous work revealed that after the first school year, students of the learning office achieved the same learning outcomes measured by the average grades [6]. Furthermore, students taught in the learning office approach felt better supported by their teachers and the satisfaction with the classrooms was higher in learning office cohorts [8]. Students of the learning office also reported higher levels in critical

thinking, personal responsibility, openness, and self-efficacy at the 10^{th} grade and students were additionally more likely to provide a meaningful written self-reflection in the learning office at grade 10 and 11, indicating higher levels of reflective thinking. Furthermore, learning office students were reportedly more likely to cooperate with peers [6] and students stated that they like going to school more in the learning office [8]. Finally, the dropout rate of the first learning office cohorts was notably lower than in the traditional approach [8].

The leading reason for dropping out of school is missing too many school days [25]–[27]. Since students perceiving facilitative core conditions are less absent [1] and learning office students are reportedly more satisfied with their teacher support as well as classrooms and like going to school more, it is hypothesized that learning office students miss fewer school days. This would be a contribution to lowering the dropout rate and thus increase the number of students benefiting from the advantages of the learning office approach and higher education. At the same time, the learning office is bound to a curriculum, which is why the learning outcomes should not differ. Furthermore, the opinion of the main stakeholders, which are students and teachers, should also be captured in a qualitative way to gain insight into the advantages and challenges of the new approach. Therefore, the following research questions are addressed in this contribution:

RQ1: Do learning office students acquire the same subject-related learning outcomes compared to students of the traditional approach?

RQ2: Do students of the learning office evaluate courses differently if they are taught in the traditional way?

RQ3: Which advantages and challenges of the learning office approach occur to teachers?

RQ4: Is the number of students' absent days lower in the learning office compared to the traditional approach?

III. Methodology

The research framework of the learning office study is based on an observational study design with elements of quasi-experiments [6], [8]. To answer the posed research questions, the following research instruments were employed:

Analysis of final grades (I1): To compare the learning outcomes of learning office students with students taught in traditional classrooms, an analysis of the final grades of students upon completion of the winter term in January 2020 at the grades 9–12 has been conducted, encompassing 16 cohorts and 401 students in total. Since every school subject is seen as equally important, the average grade of students was used as an indicator of the overall learning outcome. The average grade is a common measurement of the overall performance in Austria [8] and calculated by averaging all grades using the following mapping: A=1, B=2, C=3, D=4, F=5. Students repeating the current school year were excluded as most of them only had to repeat failed subjects, which is why no fair and stable average grade could be calculated. The used grading schemes in a subject were dependent on the teachers. Since most educators teach in both approaches, the teachers' influence between approaches should be minimal. Furthermore, most subjects taught in both approaches use centralized exams, which make up most of a student's grade.

Course feedback questionnaire (I2): Course feedback has been collected from one learning office cohort at grade 11 in two different subjects to qualitatively investigate and compare the opinion of students on a learning office subject and a traditional subject. The standardized questionnaire commonly used at the IT department contained eleven statements to be rated on a four-point semantic differential scale [28] from "agree"[1] to "disagree". Students could also provide written feedback via two open-ended questions asking them for positive feedback as well as suggestions for improvement. The questionnaire was answered by 21 and 23 students respectively in 2019.

Expert interviews (I3): To collect qualitative feedback from teachers as second important group of stakeholders, expert interviews have been conducted with ten teachers, one of which taught at a different technically oriented secondary schools. The experts received the script in advance and were asked for their opinion on the learning office in the context of digital transformation and its impact on the classroom in individual interview sessions. Based on the transcriptions, a thematic content analysis was conducted to find common categories. The experts were also asked to rate the potential of the learning office approach in comparison to other self-directed approaches and tools for teaching and learning. The investigated tools were chosen based on the literature on learner-centered engineering education.

Evaluation of absent days (I4): Since the school relies on a physical class register, a quantitative comparison of the attendance has not been feasible until now. However, since the school year 2019/20, both approaches use a common laboratory setting at grade 12 in which the visited lab needs to be captured electronically, allowing for a statistical evaluation of students' absence days for the first time. Students spend 12 lessons per week in this setting, which makes up one third of their total number of lessons. As students repeating the school year were exempted from many subjects, they were also excluded from this analysis. A lab day was counted as absent if a student's attendance was not registered by a teacher.

IV. Results and Interpretation

A. Analysis of Final Grades (I1)

1) Results: Fig. 1 and Table II show the grade point average distributions in both approaches at the grades 9–12 at the end of the winter term 2019/20. The observed differing distributions at *grade 9* confirm previous findings showing that learning office students struggle in their first semester due to the change of school and system [6], [8]: The median average grade was 2.84 in the learning office and 2.38 in traditional classes. A Kruskal-Wallis test with underlying null hypothesis of equal location parameters returned a highly significant result of p=0.0075. This supports the hypothesis

[1]Statements, scales, and quotes of teachers as well as students have been translated from German.

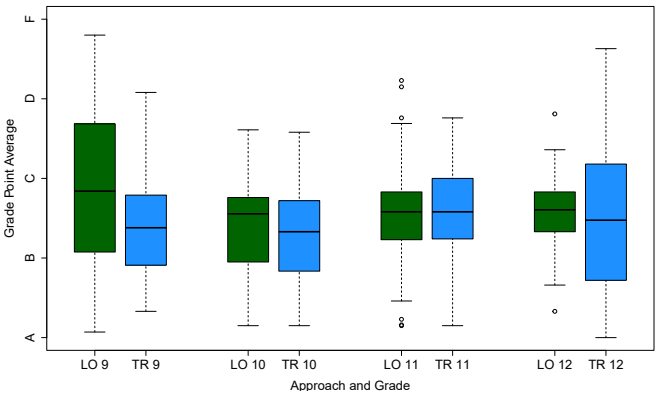

Fig. 1. Grade Point Averages of all Grades (9–12) in Learning Office Approach (LO) and Traditional Approach (TR)

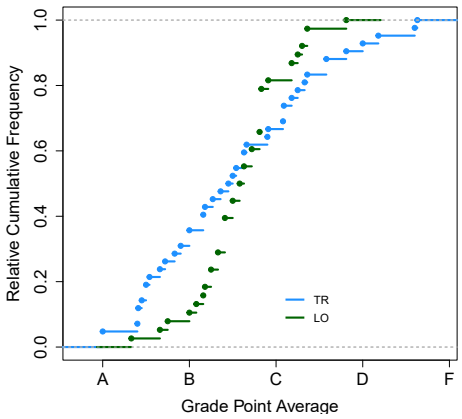

Fig. 2. ECDF of Grade Point Averages in Learning Office Approach (LO, N=38) and Traditional Approach (TR, N=42) at Grade 12

TABLE II
SUMMARY OF GRADE POINT AVERAGES OF ALL GRADES (9–12) IN LEARNING OFFICE APPROACH (LO) AND TRADITIONAL APPROACH (TR)

Cohort	N	Min	Q1	Med	Mean	Q3	Max	SD
LO 9	59	1.07	2.08	2.84	2.90	3.69	4.80	0.955
TR 9	63	1.33	1.91	2.38	2.42	2.79	4.08	0.670
LO 10	40	1.15	2.01	2.56	2.39	2.76	3.61	0.633
TR 10	55	1.15	1.84	2.33	2.31	2.72	3.58	0.604
LO 11	41	1.15	2.23	2.58	2.54	2.83	4.23	0.712
TR 11	63	1.15	2.24	2.58	2.51	3.00	3.76	0.603
LO 12	38	1.33	2.33	2.61	2.60	2.83	3.81	0.506
TR 12	42	1.00	1.75	2.48	2.53	3.16	4.63	0.950

that some learning office students need to take their time to get settled in the new way of learning. In addition, the grade point average was spread notably wider in the learning office. Assuming interval data, a Shapiro-Wilk test of the null hypothesis that the sample data follow a normal distribution returned a significant result of p=0.0389 for the distribution of the traditional system, rejecting the normality assumption. A Levene's test, which tests the hypothesis of equal variances of two samples and is robust against non-normal distributions, returned another highly significant result of p=2.53*10^{-4} with a sample variances ratio of 2.033.

Learning office students have shown to adjust to the new system quickly. The shown distributions of *grade 10* highlight that learning office students have completed the adjustment to the self-directed approach after one year: No significant differences could be found, which is an indication that students of both approaches acquire the same learning outcomes.

Similar distributions could be observed at the 11^{th} grade. Some minor outliers could be observed in the learning office in both directions. However, they did not induce a significant difference in the spreading or location of the distributions.

Interestingly, *grade 12* revealed two notably different patterns: While the grade point averages of learning office students were allocated densely around the center, a distinctly wider spread distribution was observable in the traditional approach. This extensive spreading closely resembles the distribution in the learning office at the 9^{th} grade. Since both distributions did not significantly differ from a normal distribution in a Kolmogorov-Smirnov test as well as a Shapiro-Wilk test under the assumption of interval data, normality of the data is assumed. An F-test of the hypothesis of equal variances returned for grade 12 a highly significant result of p=1.77*10^{-4} and a ratio of the sample variances of 3.534. The location parameters did not significantly differ.

Fig. 2 shows the empirical cumulative distribution functions (ECDF) of the grade point average of both approaches at grade 12. The learning office revealed a typical S-shaped ECDF indicating a normal distribution, while the distribution of the traditional approach is rather right-skewed towards failing grades. While approximately 10% of the students in the traditional setting had a grade point average of 4.0 (D) or higher, the same percentage of learning office students could be found above the 3.3 mark. In addition, at a grade point average of 3.81 the ECDF of the learning office reaches 100%, i.e. no learning office student had a grade point average of 4.0 or above. However, at the same time, lower grade point averages were also more frequent in the traditional approach, resulting in an interquartile range of 1.41 compared to 0.5 in the learning office.

2) Interpretation: The results confirmed previous findings showing that learning office students need one or two semesters to get used to the new system [6], [8]. This is completely understandable and natural: Students not only have been used to traditional classrooms for at least eight years, but have also never had technical school subjects like software development. This major twofold change requires time to get used to. At the 10^{th} and 11^{th} grade, no significant differences could be found, indicating that the overall learning outcome is the same in both approaches.

Grade 12 allowed for another interesting observation. The dense distribution in the learning office showed that students tended to complete the semester with a rather reproducible grade point average. In contrast, the traditional approach revealed a widespread and right-skewed distribution of the average grade closely resembling the initial distribution of the learning office at grade 9. A possible interpretation of

this observation is that the freedom that comes with the 12^{th} grade requires students to be more independent and self-reliant as they work together in IT projects and do lab work in groups. Hence, students taught in traditional classrooms live through a similar change of systems learning office students had already experienced in their first year, which could be an explanation for the similar widespread distributions at grade 9 and 12. Some students struggle with the granted freedom at first, resulting in outliers towards failing grades.

The overall learning outcomes measured by the average grade did not significantly differ regarding the median value and therefore seem to be equal in both approaches after the first school year.

B. Course Feedback Questionnaire (I2)

1) Results: Copies of the standardized course feedback questionnaire were handed out to the 24 students of one cohort at grade 11 to collect feedback on a learning office subject and one traditional course. Software development was chosen as representative for the technical learning office and IT projects as the counterpart held in the traditional mode. The intention by choosing these two subjects was to minimize bias and improve comparability: First, both courses are technical subjects, which means that students are relatively new to both of them. Second, the courses were partly held by the same teachers. Third, the subjects are two of the three subjects with the most hours per week in total over all five school years, which means that both courses account for a significant part of the students' technical education.

The results of the 21 and 23 responses are shown in Fig. 3. The respective response rates were 87.5% and 95.8%. The overall feedback on both courses was very positive. The most criticized factor was the *course material* in both cases. *Active involvement* and *practical relevance* were also reported to be in need for improvement, especially in the learning office subject.

The last noteworthily rated factor was the *course structure*. 22% of the students rather disagreed that the IT projects course was well-structured, while all of the students rather agreed or agreed with this statement in software development. This difference was significant with p=0.0267 using a Kruskal-Wallis test of the hypothesis of equal location parameters.

The written feedback on what students liked about the course could be divided into two major groups in each subject. The positive feedback in *IT projects* comprised 18 written responses and was categorized the following:

Feedback (7): Seven students mentioned that they especially liked the way feedback was handled in the IT projects course. Since students are used to consulting their teachers anytime they want in the learning office, the feedback culture seems to be familiar to them and makes them feel comfortable.

Project work (4): Four students appreciated the practical relevance and freedom related to the project work, which is a characteristic they know from many learning office subjects.

Software development encompassed 14 written responses:

Support (6): Interestingly, the positive feedback in software development did not tend to mention the term "feedback" as

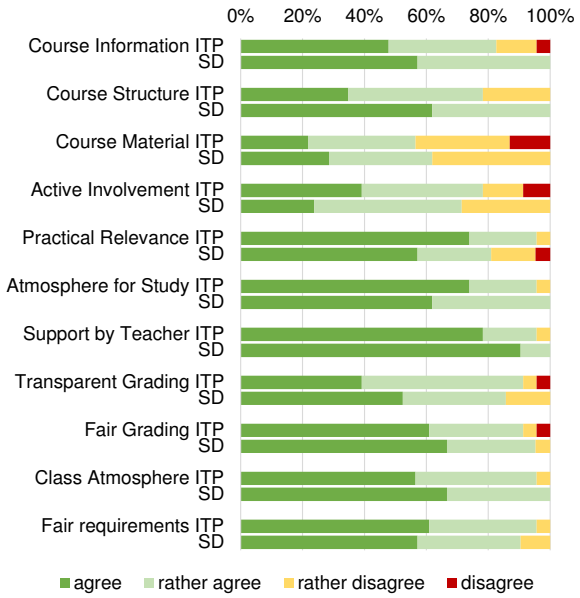

Fig. 3. Course Feedback in traditional subject IT projects (ITP, N=23) and learning office subject software development (SD, N=21)

such – only one response contained this word. The responses could be rather categorized as "support". This may be an indication that teachers of the learning office are not seen as a "grading authority" who just provides feedback, but are rather regarded as coaches supporting students in their learning.

Teacher (4): Four responses highlighted the teachers and their behavior or attributes, such as their friendliness and motivation. This could be an indication of the person-centered attitudes of the teachers.

The remaining answers were too different to be clustered.

2) Interpretation: Provided that a lot of effort is put into preparing self-explanatory *course material* for the software development course, while the IT projects course solely relies on PowerPoint slides and exemplary sample solutions for the exercises, it is rather surprising that they were rated similarly. A possible interpretation could be that students have higher expectations in learning office subjects regarding the used course material, since they are supposed to study the subject matter on their own. In the software development course, seven students provided written answers on the question asking for suggestions for improvement and mentioned the scripts. This highlights that the course material plays an important role in learning office subjects.

Active involvement and *practical relevance* seemed to be rated slightly better in the IT projects course compared to software development. Small exercises to be solved alone may not be as engaging as working on projects in groups. However, this is rather a result of the curriculum and the centralized exams than an issue of the learning office: All students need to be able to solve the same tasks at some point.

Students appreciating the *course structure* of software development probably originated from the thoughtfully prepared e-learning course. The Moodle course gives an overview of all

course modules, exercises, material, and important dates. An outline of the course can be found in previous work [8].

The positive written feedback in IT projects was found to center on feedback and project work, while students rather talked about their teachers and the support they receive in the learning office subject. This finding is especially interesting since both subjects were held by partly the same teacher, which could be an indication that the learning office setting promotes students' perception of a teacher's person-centered attitudes. Another interpretation could be that learning office teachers have different characteristics.

C. Expert Interviews (I3)

1) Results: Six of the ten interview partners were active teachers of the learning office. All interviewees were familiar with the concept of the learning office. One interview partner was skeptical about the learning office approach, since they felt that the role of a coach would be too passive for them. Six interviewees stated that they see the learning office as a very positive approach. Three interviewees were neutral and highlighted that both approaches have their own advantages. The transcripts of the interviews were analyzed and the mentioned advantages and challenges were categorized. The following listing summarizes the *advantages* of the learning office approach, as seen by the interview partners:

Self-reliance (5): Five interviewees saw a strong connection between the learning office approach and self-reliance. Since students are fully responsible for their own learning progress, they acquire the necessary personal competences to become self-reliant, which is an essential skill in the 21^{st} century.

Individualization (5): Half of the interview partners named individualization as a characteristic of the learning office. Students may specialize in certain areas, deepen their knowledge, and set and pursue their individual focus of interest. Students who are gifted in a certain area get the support they need.

Supports more and weaker students (5): The same number of interviewees stated that the learning office especially supports weaker students or is able to reach more students than the traditional system. As a result of the clear distinction between basic and advanced exercises, students who struggle with a certain subject are able to focus on the very basics and do not feel overwhelmed by advanced topics.

Work at own pace (2): Two interviewees highlighted the advantage that students may work at their own pace. This is also a benefit if a student is sick for several days or weeks: In the traditional system, teachers keep introducing new content a sick student would miss, while the learning office approach enables students access to the content any time they want.

Relationship (2): Another two interview partners stated that the student-teacher-relationship was stronger or more individual. Since teachers do not give lectures, they are able to spend more time with each individual student.

Better learning material (1), *more cooperation* (1), *higher intrinsic motivation* (1): These three advantages were mentioned by one interview partner each.

The following *challenges* were identified:

TABLE III
EXPERT RATINGS OF SELF-DIRECTED APPROACHES AND TOOLS FOR TEACHING AND LEARNING

	Rating (1–10) of Interviewee (P1–P10)											
Self-Directed Approach	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	$\bar{x}$	$\tilde{x}$
learning office	7	5.5	8	4	9	9	10	10	5	9	7.65	8.50
flipped classroom	7	9	8	6	8		10	10	3.5	10	7.94	8.00
MOOCS	7	5		7	6		7			8	6.67	7.00
Teaching and Learning Tool	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	$\bar{x}$	$\tilde{x}$
Codecademy	7	9	8	7	7		10	8	9		8.13	8.00
Moodle quizzes	3	10	5	3	2	8	10	10	8	8	6.70	8.00
peer review	8	8	7	1	8	9	7	7	5.5	8	6.85	7.50
learning videos	7	10	9	6	7	7	10	5	5.5	10	7.65	7.00
mobile learning apps	6	10	8	5.5	6	7	9	3		9	7.06	7.00
Git Classroom	5	5	7	4			8	7	9.5		6.50	7.00
lecture recordings	5	7	5	7.5	5	7	4	5	8	9	6.25	6.00
digital scavenger hunt	5	8.5	6	4	6	5	6	5	7.5	7	6.00	6.00
jigsaw technique	7	7	7	5	5	6	8	4		1.5	5.61	6.00
Kahoot!	3	10	7	2	4.5	2	10	5	5	3.5	5.20	4.75
lecture livestreams	5	5	3	7.5	3	3	1	8	1.5	4.5	4.15	3.75

$\bar{x}$: Arithmetic mean
$\tilde{x}$: Median value

Not for every kind of learner (3): As in traditional approaches, not every kind of learner could be addressed by the learning office according to three interview partners. Additional work needs to be done in both approaches to reach more students in multiple ways.

Effort for teachers (2): Creating self-explanatory course material requires teachers to invest additional time. Furthermore, supporting students during class is also more challenging for teachers of the learning office: Most of the time, they have to keep the whole course content and exercises of the current semester in mind, or even multiple grades.

Some general remarks were that students need time, about one or two semesters, to adjust to the novel way of learning and that it is a big benefit that both approaches are offered at the IT department. This enables not only students to choose between both systems, but also teachers.

Excerpts of the ratings of the potential of the selected tools for teaching and learning as given by our interview partners were summarized in a thesis [29]; the detailed ratings sorted by the median values are shown in Table III for the first time. If an interview partner did not know a method or did not feel to know it well enough to rate its potential, the rating of the respective method was skipped and excluded. Interval estimations were converted to the average of the estimated boundaries for easier use. One tool was excluded from the evaluation due to the small number of interview partners who were familiar with it, namely Office Classroom.

The learning office achieved the highest score (8.5) of the self-directed approaches measured by the median value, closely followed by the flipped classroom concept (8.0). MOOCs were also seen as a useful approach (7.0).

The web-based coding training tool Codecademy [30] and Moodle quizzes [31] both reached the highest median score (8.0) in the tools category, followed by peer review (7.5) as well as learning videos, mobile learning apps, MOOCS and Git Classroom [32] (7.0). Lecture recordings, digital scavenger

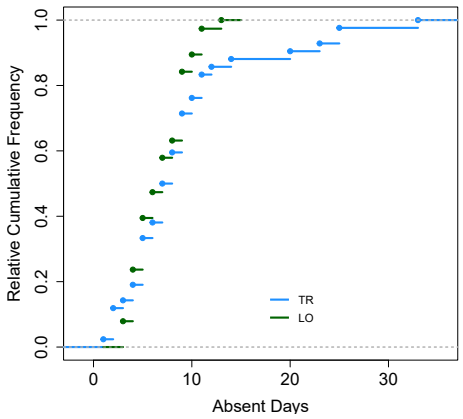

Fig. 4. ECDF of Absent Lab Days in Learning Office Approach (LO, N=38) and Traditional Approach (TR, N=42) at Grade 12

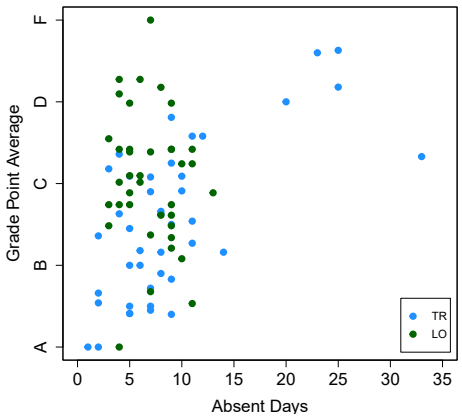

Fig. 5. Grade Point Average in Relation to Absent Days in Learning Office Approach (LO, N=38) and Traditional Approach (TR, N=42) at Grade 12

TABLE IV
SUMMARY OF ABSENT DAYS AT GRADE 12 IN LEARNING OFFICE APPROACH (LO) AND TRADITIONAL APPROACH (TR)

Cohort	N	Min	Q1	Med	Mean	Q3	Max	SD
LO 12	38	3	5	7	6.92	9	13	2.675
TR 12	42	1	5	7.5	9.02	10	33	6.873

hunts, and the jigsaw technique (6.0) were seen as tools with moderate potential. Interestingly, Kahoot! [33] was not trusted with a high potential (4.75) by the interview partners, although we found that it is seen as a useful learning tool by students [34], [35]. The interviewees stated that Kahoot! is a good tool to motivate students and review topics, but not suitable for studying completely new topics, resulting in a rather low rating of overall potential. Lecture livestreams (3.75) were assigned the lowest rating, since they provide no additional benefit to lecture recordings and are time-constrained.

The interview partners identified the following additional modern tools for learning: Learning paths, which guide students through an e-learning course using conditional visibility, learning games, and Google classroom [36].

2) Interpretation: A majority of the interviewed teachers had a positive attitude towards the learning office approach. The strongest advantages half of the interview partners highlighted were the fostering of the self-reliance of learning office students, the possibility to individualize and specialize, and the support weaker students are offered by this concept. Teachers value that both systems are offered at the same time, allowing students as well as teachers to choose between them.

The learning office was trusted with the highest overall potential of the selected self-directed approaches. Overall, the interviews indicated that the learning office is a viable approach to cope with the results of the progressing digitization and prepare students for the challenges of the 21^{st} century.

D. Evaluation of Absent Days (I4)

1) Results: The ECDF of the absences on lab days at the 12^{th} grade are shown in Fig. 4. While the absent days were once again rather S-shaped in the learning office, the traditional approach revealed another right-skewed distribution towards higher absent days. Table IV summarizes both distributions. Although the median values did not notably differ, the mean, maximum, and standard deviation were distinctly higher in the traditional approach due to the high number of "outliers" responsible for the skewness. A Shapiro-Wilk test of the hypothesis that the data are normally distributed rejected the normality assumption for both the learning office (p=0.0409) and the traditional approach ($p=4.7*10^{-6}$). A Levene-test with underlying null hypothesis of equal variances returned p=0.0225, indicating a highly significant difference in the dispersion with a sample variances ratio of 6.602. Although the distributions seemingly do not follow a normal distribution, the sample sizes of both distributions are larger than 30 and therefore allow for a statistical test based on an approximation using the t-distribution under the application of the central limit theorem [37]. A one-sided Welch t-test with the alternative hypothesis that the difference in means is less than 0 under the assumption of unequal variances returned a significant result of p=0.0360.

Fig. 5 shows the absences on lab days and the respective grade point average. To analyze the interaction between these variables, a correlation analysis was conducted. Pearson's correlation analysis [38] returned a highly significant moderate correlation with r_p=0.5122 and $p=1.20*10^{-6}$. However, since Pearson's correlation coefficient is rather sensitive to outliers, Spearman's rank correlation [39] was calculated in addition due to its robustness against outliers. Spearman's correlation analysis also returned a significant result, but indicated a slightly weaker relationship with r_s=0.2839 and p=0.0107.

2) Interpretation: The significant difference in the variances of the absences on lab days was a result of five outliers in the traditional approach. They were also responsible for the significantly different means in favor of the learning office approach. However, the question arises if five of 42 students struggling with their grade point average and absences in their fourth year at school are truly "outliers" or rather a pattern of the traditional approach: Some students may find it difficult to cope with the responsibility that comes with the provided

freedom at grade 12. Since learning office students have been used to this kind of freedom from the beginning, the 12^{th} grade does not pose a challenge for them. The significant correlation between the absent days and grade point average support findings of the literature reporting a strong connection between absent days and the dropout rate [25]–[27].

V. Discussion

A. Findings

Several interesting significant findings were discovered. The research questions could be answered the following:

RQ1: Do learning office students acquire the same subject-related learning outcomes compared to students of the traditional approach?

Students of the learning office acquired the same learning outcomes measured by the average grade after the first school year, confirming previous findings [6], [8]. Learning office students also revealed a notably denser distribution of the average grade at the 12^{th} grade, while the traditional approach showed a widely spread distribution. This could be an indication that some students taught in traditional classrooms struggle with the provided freedom of the 12^{th} grade, which was not the case in the learning office.

RQ2: Do students of the learning office evaluate courses differently if they are taught in the traditional way?

Yes, according to the feedback on the two selected courses. Learning office students rated the course structure of the representative learning office subject significantly better than the traditional subject. They also tended to highlight the teachers' attributes and support in the learning office subject, while the positive feedback on the traditional subject addressed the feedback modalities and project work. Learning office students also seem to have higher expectations of the used course material in learning office subjects, since they did not rate it notably better despite the increased effort for preparation.

RQ3: Which advantages and challenges of the learning office approach occur to teachers?

The most commonly mentioned advantages were an improved self-reliance, enabling individualization, and supporting weaker students. Two mentioned challenges were an increased effort for teachers as well as that the learning office does not fit every kind of learner. However, this is also the case in the traditional approach and is subject of a process of constant improvement. The interviewed teachers rated the learning office as the most promising approach of a set of 14 selected methods of learning and approaches.

RQ4: Is the number of students' absent days lower in the learning office compared to the traditional approach?

Yes, measured by the absences on lab days at the 12^{th} grade. Learning office students missed significantly less lab days than their traditional peers, mainly caused by five outliers in the traditional approach. They also induced a significant difference in the variance of the absent days. Furthermore, a significant correlation between the grade point average and the number of absences on lab days was found.

B. Notes

Despite the distinct results, there are several known limitations of this study. First, no random group assignment was used, which means that no causalities, but only statistical associations could be assessed. Randomly assigning students is neither feasible nor possible – we want our students and parents to be able to choose between both approaches according to their individual learning preferences. Second, the freedom of choice introduces a natural bias, which cannot be eliminated. Finally, there may be additional variables than the selected approach influencing the results, like the teachers. We need to work with given restrictions in the educational field.

To protect our learners from any possible harm that could arise from this study, multiple precautions were taken. First, the analysis was carried out on strictly anonymized data. The identity of an individual was not disclosed at any point during the evaluation. Second, our students know that the learning office is accompanied by a scientific study and agreed to take part in it by registering at the department. Finally, the study was authorized by the Austrian Federal Ministry of Education.

VI. Conclusion

In conclusion, multiple indications supporting the learning office approach as a viable approach to 21^{st} century education were found. It was shown that students taught in the learning office approach achieve the same learning outcomes as their peers of the traditional system measured by the average grade after the first school year. Since they are taught in a student-centered and self-directed approach, they acquire additional 21^{st} century skills as suggested by the literature [2], [3], [7], [8]. Learning office students also revealed a significantly denser grade point average and absent lab days distribution and a significantly lower absence rate at the 12^{th} grade. The course structure of a representative learning office subject was rated significantly better and students especially appreciated the teachers' support and attributes in the learning office subject.

The expert interviews revealed that teachers see the learning office as a valuable and practicable self-directed approach. The experts rated the learning office as the approach with the highest potential. The advantages of the approach are said to be an improved self-reliance, enabling individualization, supporting weaker students, working at their own pace, and an improved relationship between teachers and students.

Future work involves follow-up studies, including repeating the experiments, a pre-screening to detect selection bias, and capturing teachers' opinion in a direct comparison between the learning office and the traditional approach.

Overall, the findings of this study extend previous results and confirm the learning office as modern approach to student-centered engineering education fostering valuable 21^{st} century skills needed to succeed in the digital knowledge age.

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