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Using learning analytics to support STEAM students' academic achievement and self-regulated learning

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Abstract

The assessment of students' academic achievements helps to increase learning effectiveness by encouraging each student to recognise his/her strengths and areas for improvement. To do so, pedagogical activities that encourage direct and frequent evaluation must be considered. This paper focuses on how a learning management system such as Google Classroom (GC) together with learning analytics (LA) can be used to extract and analyse learner's data from Science, Technology, Engineering, Art and Mathematics (STEAM) course. In addition, we explore how to employ these data to support metacognitive skills such as self-regulated learning (SRL). An explanatory sequential mixed-method design research was used, and two research questions were set, discussed and analysed. Data collection involved 128 participants. Our findings confirmed the potential of using achievement-based grading rubrics data and LA tools to provide empirical evidence of how formative assessment can affect students' SRL development. While onsite experience has revealed some important initial findings, further research is needed. To validate these results, it will be necessary to perform similar analyses on datasets obtained from other schools and subject areas. Despite the increasing interest in use of LA, there is a scarcity of research on this field for secondary school education.

Keywords: *Cognitive Development, Didactics, Distance Learning, Learning Standard, Secondary School.*

Introduction

Nowadays, students need a renewal of the education system based on multidisciplinary approaches, quality teacher training and robust learning environments. Curriculum aspirations in Science, Technology, Engineering, Arts and Mathematics (STEAM) are formulated in adolescence, making compulsory secondary school years a critical period for identifying the cognitive and motivational factors that increase the likelihood of future STEAM employment (Wang, Ye and Degol, 2017). STEAM education has received much attention in recent years; however, the specific nature and significance of STEAM education have not been clearly defined (Bybee, 2013). Vescio, Ross and Adams (2008) propose that more considerable attention to how teachers embody STEAM teaching methods is necessary for successful implementation. From this point of view, the integration does not require updated content, but the application of knew learning methodologies and tools (Conde et al., 2021). In STEAM courses, students are confronted with challenging themselves to master large amounts of interdisciplinary content while developing as autonomous and effective learners. Consequently, STEAM education community has developed an interest in metacognition and self-regulated learning (SRL) as the process of setting learning goals, monitoring progress and applying appropriate study strategies (Sebesta & Bray Speth, 2017; Stanton et al., 2015; Tanner, 2012). Nevertheless, more research is needed in this area (Harris and Bruin, 2018).

It is evident that the question of skills is becoming increasingly prominent in education. The holistic approach to the areas of development of young people has imposed itself in education as much by capillary action as by necessity. Today,

it permeates teacher practices. The assessment of students' academic achievements aims to improve learning effectiveness by allowing each student to identify their attainments and difficulties to progress. The evaluation approaches must support a constructive, simple and clear evaluation that values progress, cares motivation and encourages student creativity. The skills' dominance should be assessed based on the knowledge and skills set by the teaching programmes. The assessment of student achievement must start from the class's daily life to observe and evaluate the students' progress, while setting evaluation situations at certain precise times and always keeping the perspective of a constructive evaluation. The regular assessment of pupils' achievements is an educational activity that is not limited to specific times. To that end, it is necessary to consider pedagogical practices favouring direct and regular observation of the scholars' work in various ordinary situations. This professional practice allows teaching to be regulated dynamically and constructively. This monitoring enables educators to (1) objectify the progress made by each student, his/her development and his/her successes; (2) propose adjustments that encourage each student to engage and progress in learning; (3) use scaffolding that reinforces initial learning; (4) identify the situations ambitious enough to arouse the desire to learn even more; (5) allow teachers to deepen their understanding of the situation when a student's learning no longer changes and (6) provide to each student adapted answers to their situation (Inspection Pédagogique Régionale [IPR], 2017; Ministère de l'Éducation Nationale, de la Jeunesse et des Sports [MENJS], 2016).

Grading practices in education have remained unchanged for decades. In search of more meaningful grading performance, attention has been given to standards-based grading (SBG) practices (Brookhart, 2013). SBG measures student understanding of specific standards and, unlike traditional grading paradigms, is not influenced by non-academic factors such as behaviours and work habits (Marzano & Heflebower, 2011; Proulx et al., 2012). For this to work at school, scholars must understand what they are trying to learn and the criteria for success on these learning targets (Moss & Brookhart, 2012). Many grading authors recommend achievement-based grading (Scriffiny, 2008; Tomlinson & McTighe, 2006). Research has also revealed that grading practices are most effective when providing teachers, students and parents with specific and accurate feedback concerning academic performance. This feedback is presented on time to improve student performance (Berthier et al., 2021; O'Connor, 2009).

Because of their essential role, educators must guarantee that grading and reporting always meet validity and reliability criteria. Creating visibly standards for grades makes the evaluation process clearer and unbiassed. Regrettably, instructors commonly use broadly assortment criteria to determine students' grades, and learners are usually not well informed about these criteria. This idea provides the foundation for standards-based approaches to grading. After establishing an exact product, process and progress learning indicators, teachers assign separate grades to each indicator. The purpose is to deliver a precise and comprehensive portrait of what scholars achieve in school. The rubrics development facilitates this practice for students and families (Guskey & Bailey, 2010; Stiggins & Chappuis, 2008). The importance is to guarantee that learners recognise the range of accomplishment levels to understand what the score involves and what must be done to improve. Finally, success in grading and reporting will be amplified as technology applications are developed. This necessitates educators to provide comprehensive records of student performance, and so it gives families and learners explicit knowledge regarding student's strengths and areas of needed growth (Muñoz & Guskey, 2015). Therefore, teachers must personalise communication with students, encourage students to check resources on asynchronous hours, and, if possible, employ learning management systems to increase learner performance and interaction. This amalgamation generates an active environment since teachers can give scholars a faithful chance to improve their academic success (Arnold & Pistilli, 2012; Tinto, 2005).

Building up a whole picture of student progress and taking sentiment into account to interact with students in emotionally supportive ways are now seen as a real possibility (Blikstein, 2011). The combination uses of learning management system tools such as Google Classroom (GC) and learning analytics (LA) can extract data from distinct parts of a learner's learning environment. Then, these data can be employed to support metacognitive skills such as SRL and academic achievement (Mazzola & Mazza, 2011; Zimmerman, 2008). Teachers must have visible evidence to understand whether students are benefiting from the teaching and retaining the information. This will show where student success has progressed and where there is an opportunity for improvement. In this sense, data-based LA can be leveraged.

LA has emerged as a research area during the last decade. LA is the measurement, collection, analysis model and reporting of data about learner-produced data and their contexts to discover, improve and understand learning and social connections (Johnson et al., 2011; Ochoa et al., 2014). Teachers should use a concise learner analytics report to make a course open to apprentices. Instructors can (1) identify specific patterns; (2) propose an effective instructional design and (3) figure out if a particular methodology needs to be reviewed to make it accessible for the students and others. As LA emerges, a focus on learner's needs will be vital to build solid knowledge and enhance the learning environments. Moving away from summative evaluation towards formative evaluation benefits their development (Ferguson, 2012).

Despite the increasing interest in LA use, there is scarce research on this field for compulsory secondary school education (Ferguson et al., 2016; Martínez-Monés et al., 2017). Work focused on cognition, metacognition and pedagogy is also under-represented in LA research. Vallance and Towndrow (2016) have highlighted the need for more shared educational experiences in the classroom. Research in which teachers play an active role is extremely valuable in understanding and documenting the intentional and non-intentional effects in the dynamic classroom environment. This not only enhances the credibility and trustworthiness (Creswell & Miller, 2000) of research findings beyond the immediate context of the study, but also highlights the value of participatory approaches to research as a means of bringing together expert knowledge systems (Goff & Veresov, 2015) to tackle and solve problems that inevitably arise in classrooms.

Therefore, this paper presents how learning management system tools such as GC and LA approaches can be used to investigate intervention research with SBG assessment implementation and its effects on SRL and academic achievement, its results and the main findings obtained from them. The rest of the paper is structured as follows: Section 1 describes the research design, questions and hypotheses; Section 2 explains the methodology; Section 3 presents the main results; Section 4 gives a discussion about them and finally, the work closes with some conclusions.

1. Research design, questions and hypotheses

1.1 Research design

It should be noted that this study has been carried out in the context of a thesis research project 'Innovative secondary school STEAM curriculum through cognitive neuroscience, social–emotional learning and imaginative pedagogies transposition'. Researchers have incorporated instructional design (Gibbons & Rogers, 2009) as shown in Figure 1. In this sense, our research intervention is based on a pragmatism style as the educational paradigm, a mixed-method approach (Creswell & Clark, 2017) with an explanatory sequential design, a mixed-method sampling, a combination of qualitative and quantitative data collection and a variety of data types during the analysis phase according to Dick et al.'s (2005) system model recommendation.

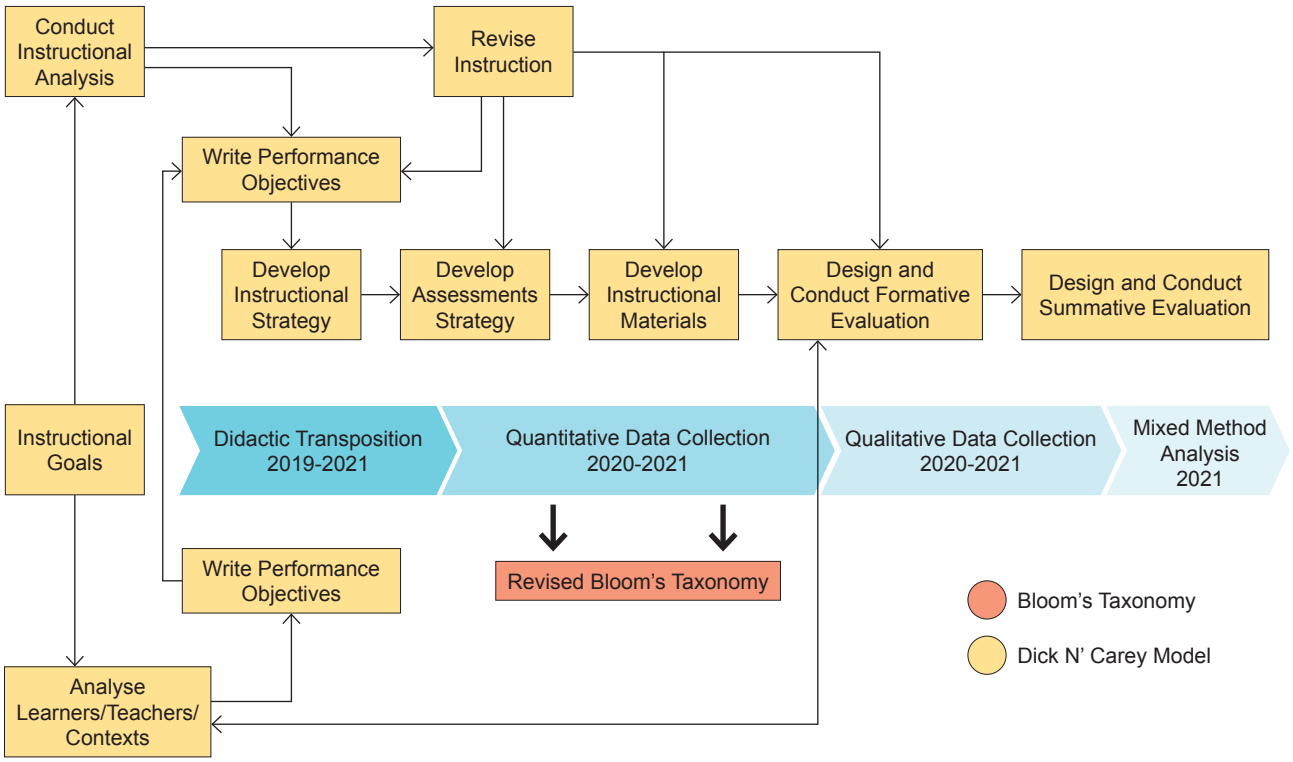


Fig. 1. Instructional design development flowchart adapted from Dick N' Carey model

1.2 Study aims and hypotheses

Through observation and interpretation of the interdisciplinary approaches that teachers adopt and develop in relation to the assessment of STEAM activities, this study aims to contribute to the challenge of understanding the use of LA and standard-based rubrics through GC to support SRL skills and academic achievement in STEAM secondary school classroom. Researchers hypothesise (H_0) that there would be a significant difference in academic achievement between STEAM students with achievement-based rubrics (ABRs) through GC and those who do not have the GC tool. As a second hypothesis (H_1), the authors stress the fact that there would be a significant difference in SRL skills between STEAM scholars with ABRs available in any format, on paper or through GC and those who do not have it.

1.3 Research questions (RQ)

- RQ1: How do the data provided by LA and GC tools help explain why ABRs through GC users have better SRL and academic achievement than those without GC access?
- RQ2: What role does mixed-methods learning research play in gaining a more comprehensive understanding of the construct?

2. Methodology

2.1 Data gathering

To answer our research questions, the study's quantitative component collected diverse types of data (Creswell & Poth, 2018): (1) academic scores data collected with or without GC and (2) LA data (access to pedagogical documents, time spent on GC, numbers of connections). A qualitative phase was conducted as a follow-up to the quantitative results. The qualitative aspects consisted of: (1) classroom observations, (2) teacher logs, (3) interviews, (4) focus group interviews with instructors and students and (5) a 20-item Likert five-point scale questionnaire (Nemoto & Beglar, 2014), designed to determine SRL skills and administered to the students at the end of the intervention period (Deci & Ryan, 2000; Gagné, 2003).

2.2 Participants

The location of the study was a compulsory secondary international French school in Gran Canaria (Spain) for students from pre-kindergarten to Grade 12. The school attracts an upper middle-class clientele desiring an internationally recognised education. The school hosts over 400 francophone and Spanish-speakers' students, whom it prepares for the Spanish BachiBac at the completion of Grade 12 as established by the national Ministry of Education in Spain (Real Decreto 102/2010, 2010). One hundred and eighteen students (12–16 years of age), of whom 58% were girls and 42% were boys, and 10 teachers, of whom 50% were men and 50% were women¸ from STEAM areas of knowledge agreed to participate and provided signed consent forms. All learners followed a secondary school education according to the curriculum established by the French Ministry of Education (Bulletin officiel n°31, 2020). This research was undertaken as part of a broader study, reviewed and approved by the local institutional review board (IRB: 20.05.2020). Researchers had asked for permission by way of informed consent forms (Slade & Prinsloo, 2014) from the school principal, instructors and parents of the students (Martínez-Monés et al., 2017). The researcher designed, conducted and collected data about the intervention from 3 September 2019 to 5 February 2020 (5 months) and from 1 September to 31 March 2021 (7 months) (intervention was interrupted due to the COVID-19 pandemic).

2.3 Procedures

Research has correlated SRL with academic performance, identifying a strong relationship between the degree to which a self-regulated learner shows a proactive and systematic engagement across all three SRL components: metacognition, motivation and behaviour. Being able to draw connections within self-regulation and academic performance depends on the instruments' reliability. In addition to surveys, researchers have also developed structured interview protocols such as the Self-Regulated Learning Interview Schedule (Zimmerman and Martinez-Pons, 1986). With a total of 128 participants, it was not possible to execute the formal interview protocol developed by Zimmerman and Martinez-Pons. Therefore, the researchers developed a Likert-type questionnaire based on an adaptation of Sebesta and Bray Speth's (2017) work, which was designed in accordance with Zimmerman's study. The questionnaire aims to determine if the use of rubrics w/o GC encourages SRL strategies to be applied and developed. Authors adapted a 20-item list to describe students' behaviours in a language that reflected the learners' experience in the context of a STEAM project. To check the internal consistency of the Likert five-point scale questionnaire, researchers performed a Cronbach's α analysis (Cronbach, 1951) through the variance of the items (Soriano Rodríguez, 2015). The initial questionnaire had 27 items, and after experts' review and previous Cronbach's analysis $\alpha = 0.951$, seven items were eliminated, until the last version was obtained with a result of $\alpha = 0.876$. It is possible to conclude that the scale has suitable validity and reliability for measuring students' SRL attitudes (Oviedo & Arias, 2005).

All students completed the same cross-disciplinary curriculum with project-based learning (PBL) as didactic methodology. Together with the main researcher, teachers involved in the project designed the pedagogical scenarisation. SBG rubrics instruments were developed as an integral part of the assessment frameworks. Several scenarios were considered: (1) GC use as a didactic tool; (2) the use of rubrics as an assessment tool and (3, 4) the absence of both in the teaching practice. With the STEAM Insect – Hotel Challenge, over a period of 12 academic weeks, the students worked with their Maths, Science, Art and Design & Technology teachers to answer the question: What would happen if bugs went extinct? In class, students worked in permanent cooperative and collaborative groups of four or five to solve problems and apply their understanding in a variety of tasks (discussions, worksheets, technical specifications reports, laboratory practice reports, mind mapping, etc.). Every one of them was associated with a competence defined by level of acquisition described in terms of a rubric. The participants were immersed in a context where all of them (teachers and students) had their tablet (iPad) to use both in the educational centre and at home.

3. Results

As regards RQ1, researchers analysed data and scores provided by LA and GC tools. The student participants were distributed in four different research groups (RG): (1) RG Nº1- with ABR sheet through GC at the beginning of the activity and after evaluation (2020–2021); (2) RG Nº2- with ABR paper sheet at the beginning of the activity and after evaluation

without GC (2019–2020); (3) RG Nº- without ABRs available in any format, however with GC access (2020–2021) and (4) RG Nº4- without ABRs available in any format or GC access (2019–2020).

Kolmogorov–Smirnov (Lilliefors, 1967) probability distributions test was performed: D = 0.7746 > *P* (non-significant); *P* < 0.0581. Besides this, Levene's test (Levene, 1960) for equality of variances was found to be infringed for the present quantitative data analysis: $W = 8.3281$; F = 2.6435; $P = 2.78 \times 10^{-5}$; df = (3.232). Owing to these broken assumptions, a statistic not assuming homogeneity of variance and non-normal distribution was computed. Kruskal–Wallis test (Kruskal & Wallis, 1952) was conducted to examine the differences in SRL skills attainment. To analyse data using a Kruskal–Wallis test in an appropriate way, four assumptions are required: (1) the dependent variable (academic scores) is measured at the ordinal level, (2) the independent variable consists of two of more independent groups (w/o GC and w/o ABR); (3) there is an independence of observations and (4) is suitable in non-normally distributed data. As shown in Table 1, no statistical significance was found among the four categories of participants.

Table 1. Kruskal–Wallis test.

Research group	n	Mean rank	Statistics	
RG Nº1	59	102,602	*H*	6.24923
RG Nº2	59	113,551	*P*	081151
RG Nº3	59	133,212	df	3
RG Nº4	59	124,636	A	0.05
Total	236			

Kruskal–Wallis test lets us know if the results are significant overall, but it will not reveal exactly where those differences lie. Following that, we conducted a non-parametric Dunn's multiple comparison test (Dunn, 1964) to determine which groups' means differed. The test compares all pairs of mean ranks. Dunn's post-hoc test revealed statistically significant pairwise differences concerning RG Nº 1 and RG Nº 3 & 4, as shown in Table 2.

Table 2. Dunn's multiple comparison test.

Research group	*H*	*P*
RG Nº1 vs RG Nº2	-0.8711	0.3837
RG Nº1 vs RG Nº3	-2.4353	0.0149
RG Nº1 vs RG Nº4	-1.7530	0.0796
RG Nº2 vs RG Nº3	-1.5642	0.1178
RG Nº3 vs RG Nº4	0.6823	0.4950

With respect to RQ2, it is important to note that our study, conducted with a sample of 118 students, did not aim to measure SRL as a quantifiable characteristic of each learner. Researchers were aware of the inherent limitations of self-reported data because it is known that learners' perceptions of their strategies may not correspond entirely to their behaviour (Schellings and Van Hout-Wolters, 2011; Veenman, 2011). Authors analysed the frequency of responses by pooling 'very often' (5) and 'often' (4) into a single category, which we refer to as 'higher use'. Conversely, the responses 'sometimes' (3), 'rarely' (2) and 'never' (1) were pooled into the single category of 'lower use'. In the survey, 84.6% of the students reported that goal access accompanied by descriptions and their degrees of attainment, as well as the availability of deadlines and frequent reminders, helped them to achieve the goals in time. Likewise, 82.1% pointed out that organised information, through the GC environment, facilitated better information access to the different materials, and therefore favoured learning. Also, 52.6% of learners positively valued the fact of being able to communicate with their classmates and teachers, which helped them whenever they did not understand a concept or information, and they received quick and personalised feedback. When asked whether the use of GC had increased their academic results, 59% answered in negative. When the same question referred to rubric implementation, 73.1% did highlight that it helped them to improve their learning, and therefore their academic results.

Multiple sources of quantitative data and qualitative data (memo writing, interview transcripts, Likert questionnaire results, etc.) were used for a more comprehensive understanding of the construct (Saldaña, 2021; Corbin & Strauss, 2014). Furthermore, the triangulation of such data reassured the study's validity and reliability (Lincoln et al., 2011; Creswell & Miuller, 2000). The analysis and interpretation of the transcriptions and documents gathered were especially useful in understanding the contradictions between quantitative results and qualitative findings. Below are some transcription excerpts recorded throughout the focus group sessions (see Figure 2) as well as during interviews, reflecting participants' point of view which ensured that the study findings are grounded in participants' experiences.

Regarding the use of rubrics, the students involved emphasised how helpful these were and the importance of receiving feedback for their self-learning: Student 1: '… I really like it when teachers share and explain the rubrics before doing the

exercise, as I can be more easily guided while doing the task. Also, when they complete the rubric with their comments, it helps me not to make the same mistakes the next time…'; Student 2: '… The rubric helps me not to forget things that are important to the teacher but were not important to me. In the end, when you get the feedback, you end up understanding better what each teacher wants for each homework assignment…'. However, teachers' opinions were divergent between their efficiency and the workload required to implement them: Teacher 1: '… I was a bit surprised by the results. I thought there would be a quantifiable positive impact of using Google Classroom on student performance. Because I am persuaded that there is a qualitative impact, on the submission of homework, and in self-regulated learning, on the students' motivation…. In addition, Google Classroom (GC) saves time and facilitates the management of teacher's tasks which eventually translates into more diversity and personalisation of the activities for learners…'; Teacher 2: '… The creation of rubrics is recommended in the curriculum, but the reality in the field means that we do not really have the time or guidelines or references to personalise and create them according to our teaching programmes. It would be important to share these data with the school management so that they rethink the time dedicated to the construction of didactic actions, to encourage the use of this type of tool by the teaching staff as a whole…'.



Fig. 2. Picture showing focus groups conducted with students and teachers

4. Discussion

Our hypothesis (H0) that there would be a significant difference in academic achievement between STEAM students with ABRs through GC (Research Group (RG) Nº 1) and those who do not have the GC tool (RG Nº 2 & 4) has been rejected by the significance testing results, since there are no substantial variations in academic scores related to student achievement influenced by the GC effect. Nevertheless, Dunn's test results supported the hypothesis (H1) that there would be a significant difference in academic achievement between STEAM scholars with ABRs available in any format, on paper or through GC (RG Nº 1 & 2) and those who do not have it (RG Nº 3 & 4).

The practice of evaluation by competences comes to work on the balance between the prescribed (Decree No. 2015-372) and the induced framework of the teaching mission. Where the normative approach and the deontology of the teacher propose an obvious, but simple framework that can govern the evaluation, a more axiological approach invites him/her to ask the question of meaning, of what he or she is trying to evaluate, of taking into consideration specificity of the learners and diversity of the public. The design and implementation of ABRs allow to integrate a paradigm shift as a lever for a real reflection on evaluation, to make it a facilitating tool for a policy of harmonisation of practices and coherence within STEAM educational teams.

It is through the feedback provided by GC via the rubric, which includes important dimensions of performance, as well as the standards for achieving these criteria, that students will self-correct and self-improve in their next output, thanks to the communication fostered by the knowledge of what is considered important and what to look for in the assessment, integrating the learning process as a part of the formative logic of assessment. Consequently, what is at stake is not only a test of knowledge, but also an assessment of competence, the essential function of which is to transform the process of grading into 'a lever for learning' (Amale, 2021, quoted in Bourguignon, 2010, p. 63). The ABRs can, therefore, help to effectively integrate the learner into the evaluation process. They constitute a reference point and a tool to help in the evaluation of productions; they are used to guarantee maximum objectivity. This reflective posture offers the learner an individualised and adapted learning moment. As a result, it is this awareness that allows the learner to gradually become the conscious and autonomous actor of his/her actions and knowledge. To ensure a more structured assessment process, to achieve a more effective evaluation outcome, researchers recommend the use of ABRs that would be beneficial to students.

Conclusions

Regarding RQ1, how do the data provided by LA and GC tools help explain why ABRs through GC users have better SRL and academic achievements than those without GC access? In line with the results obtained by Amale (2021), quantitative data supports positive values evidence of standards-based rubric use regarding academic achievements. Nonetheless, this impact is not causally related to the use of learning management systems like GC. The qualitative results are in line with the research carried out by Bjork et al. (2013) and Gilovich (2008), where the importance of distinguishing

illusion and reality in relation to self-learning is highlighted. Learning to be good observers of himself/herself helps students to avoid impasses, to make good decisions and to think about how they might move forward. It is this skill that is undermined when students and teachers begin to delude themselves about their abilities. The way to guard against illusions and other errors of judgement is to stop basing choices and decisions on subjective experience, and instead to base them on a set of objective indicators, which show the importance of deploying data analysis from tools such as LA and GC. The results contribute to understanding interactions' importance in asynchronous learning (Bernard et al., 2009), even if such outcomes contradict the literature on online opinions about the importance of facilitating engaging interaction with stimulating content to foster learning achievement (Joksimović et al., 2015).

In this research study, 11.86% of the total number of participants were students with special needs. The inclusive school (No. 2005-102, 2005) and the 'school of trust' (No. 2019-791, 2019) French laws aim to ensure quality instruction for all students from kindergarten to high school by considering their particularities and special educational needs. These laws on special needs students come as an outcome of the already existing arrangements. The school institution, through legislation, is confirming that it is up to the society and communities to adapt. For this reason, the school's policy requires all teachers to create a series of adaptations for the inclusion of these students in the classroom on an equal footing with the rest of their classmates. Discussions with students and teachers throughout the study confirm the helpfulness of LMS (Learning Management System) like GC, as well as the use of standards-based rubric on self-regulated learning skills development for this particular group of students, which can be adapted to specific competences and objectives, as recommended by the research work of Tan (2020) and Kamei and Woods (2020).

Regarding RQ2, what role does mixed-methods learning research play in gaining a more comprehensive understanding of the construct? It should be noted that qualitative data analysis via integrative mixed methods serves to contribute to a more comprehensive and nuanced understanding of these outcomes. According to Gupta and Pathania (2021) and Agudo-Peregrina et al. (2014), the mixed-method analysis reveals that teachers and students who have benefited from the intervention warrant the usage of the system. In agreement with the results obtained by Kopeyev et al. (2020), findings showed the need to incorporate LA and GC tools as a regular teaching practice. An instructor can supply action-oriented and helpful feedback much earlier throughout LA and GC, which enables students' metacognitive development, and consequently has positive effects on students' self-learning skills as underlined by Brown's (2016) work. Moreover, students tend to be more initiative-taking because of GC interventions. Additional training on the use of GC is necessary to make students feel comfortable with the tool and know how to interpret the teacher's results.

The use of GC is becoming widespread, which could help foster teachers' uptake of technology, especially at compulsory secondary school levels, where the challenge is much prominent. However, in concordance with Rodríguez-Triana et al.'s (2015) work, our findings also reveal that GC brings limited functionality. LA applications can help to fill this gap, but for doing that, it is necessary to collect data from GC at a meaningful level of abstraction (Wise et al., 2013). Furthermore, a greater understanding of indirect interactions would also be needed to improve. The research analyses the connections at four educational levels, with two classrooms per year, over 12 months, and the collected data are from the same domain (STEAM), and thus might not represent a broader range of students across different disciplines. For additional validity cover, it will be significant to perform similar studies on datasets obtained from other compulsory secondary schools, degree programmes and subject areas. In the same vein as the suggestions made by Dawson et al. (2019), we believe that further research should focus on more replication studies to enable research development.

References

Agudo-Peregrina, Á. F., Iglesias-Pradas, S., Conde-González, M. Á., & Hernández-García, Á. (2014). Can we predict success from log data in VLEs? Classification of interactions for learning analytics and their relationship with performance in VLE-supported F2F and online learning. Computers in human behavior, 31, 542-550.

Amale, G. (2021). L'impact d'une grille d'évaluation critériée et élaborée sur l'amélioration des compétences rédactionnelles en FLE au supérieur: Cas des étudiants de 1 ère année du département de français-Université Batna2-The impact of a Criteria-Based and Elaborated Evaluation Grid. *Revue des Sciences Humaines*, *21*(02), 1168-1183.

Arnold, K. E., & Pistilli, M. D. (2012). Course signals at Purdue: Using learning analytics to increase student success. In Proceedings of the 2nd international conference on learning analytics and knowledge (pp. 267-270).

Bernard, R. M., Abrami, P. C., Borokhovski, E., Wade, C. A., Tamim, R. M., Surkes, M. A., & Bethel, E. C. (2009). A meta-analysis of three types of interaction treatments in distance education. Review of Educational research, 79(3), 1243-1289.

Berthier, J. L., Borst, G., & Guilleray, F. (2021). *Les neurosciences cognitives dans la classe: Guide pour expérimenter et adapter ses pratiques pédagogiques*. ESF sciences humaines.

Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). Self-regulated learning: Beliefs, techniques, and illusions. *Annual review of psychology*, *64*, 417-444.

Blikstein, P. (2011). 'Using learning analytics to assess students' behavior in open-ended programming tasks', paper Presented at the 1st International Conference on Learning Analytics and Knowledge (LAK11), Banff, Canada (27th February – 1st March).

Brookhart, S. M. (2013). How to create and use rubrics for formative assessment and grading. Ascd.

Brown, P. C., Roediger, H. L., & McDaniel, M. A. (2016). *Mets-toi ça dans la tête!: les stratégies d'apprentissage à la lumière des sciences cognitives* (p. 1). Éditions Markus Haller.

Bulletin officiel n°31 (2020). Relatif aux programmes d'enseignement : cycle des apprentissages fondamentaux (cycle 2), cycle de consolidation (cycle 3) et cycle des approfondissements (cycle 4) : modification. Arrêté du 17-7-2020 et J.O. du 28-7-2020. 30 July 2020, NOR : MENE2018714A (France).

Bybee, R. W. (2013). *The case for STEM education: Challenges and opportunities*. NSTA press.

Conde, M. Á., Rodríguez-Sedano, F. J., Fernández-Llamas, C., Gonçalves, J., Lima, J., & García-Peñalvo, F. J. (2021). Fostering STEAM through challenge-based learning, robotics, and physical devices: A systematic mapping literature review. *Computer Applications in Engineering Education*, *29*(1), 46-65.

Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.

Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into practice*, *39*(3), 124-130. http://dx.doi.org/10.1207/s15430421tip3903_2

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *psychometrika*, *16*(3), 297-334.

Dawson, S., Joksimovic, S., Poquet, O., & Siemens, G. (2019). Increasing the impact of learning analytics. In Proceedings of the 9th International Conference on Learning Analytics & Knowledge (pp. 446-455).

Deci, E. L., & Ryan, R. M. (2000). The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. Psychological inquiry, 11(4), 227-268.

Décret n° 2015-372 (2015). Relatif au socle commun de connaissances, de compétences et de culture. 31 Mars 2015, NOR: MENE1506516D (France).

Dick, W., Carey, L., & Carey, J. O. (2005). The systematic design of instruction.

Dunn, O. J. (1964) Multiple Comparisons Using Rank Sums, Technometrics, 6:3, 241-252, DOI: 10.1080/00401706.1964.10490181

Ferguson, R. (2012). Learning analytics: drivers, developments, and challenges. International Journal of Technology Enhanced Learning, 4(5-6), 304-317.

Ferguson, R., Brasher, A., Clow, D., Cooper, A., Hillaire, G., Mittelmeier, J., Rienties, B., Ullmann, T. and Vuorikari, R. 2016. Research Evidence on the Use of Learning Analytics: Implications for Education Policy. (2016).

Gagné, M. (2003). The role of autonomy support and autonomy orientation in prosocial behavior engagement. Motivation and emotion, 27(3), 199-223.

Gibbons, A. S., & Rogers, P. C. (2009). The architecture of instructional theory. *Instructional-design theories and models*, *3*, 305-326.

Gilovich, T. (2008). *How we know what isn't so*. Simon and Schuster.

Goff, W., & Veresov, N. (2015). Examining teacher-researcher collaboration through the cultural interface. *Cultural Studies of Science Education*, *10*(3), 621-627. http://dx.doi.org/10.1007/s11422-015-9665-9

Gupta, A., & Pathania, P. (2021). To study the impact of Google Classroom as a platform of learning and collaboration at the teacher education level. *Education and Information Technologies*, *26*(1), 843-857.

Guskey, T. R., & Bailey, J. M. (2010). Developing standards-based report cards. Corwin Press.

Harris, A., & de Bruin, L. R. (2018). Compulsory secondary school creativity, teacher practice and STEM education: An international study. *Journal of Educational Change*, *19*(2), 153-179.

Inspection Pédagogique Régionale. (2017). Guide Pratique de l'Evaluation (pp. http://www1.ac–poitiers.fr/medias/fichier/guide–pratique–evaluation–15–02–2017_1487230308978.pdf). Poitiers: Académie de Poitiers.

Johnson, L., Smith, R., Willis, H., Levine, A. and Haywood, K. (2011) The Horizon Report: 2011 Edition, The New Media Consortium, Austin, Texas.

Joksimović, S., Gašević, D., Loughin, T. M., Kovanović, V., & Hatala, M. (2015). Learning at distance: Effects of interaction traces on academic achievement. Computers & Education, 87, 204-217.

Kopeyev, Z., Mubarakov, A., Kultan, J., Aimicheva, G. & Tuyakov, Y. (2020). Using a Personalized Learning Style and Google Classroom Technology to Bridge the Knowledge Gap on Computer Science. *International Journal of Emerging Technologies in Learning (iJET), 15*(2), 218-229. Kassel, Germany: International Journal of Emerging Technology in Learning. Retrieved 18th March 2021 from https://www.learntechlib.org/p/217171/.

Kruskal, W. H., & Wallis, W. A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American statistical Association*, *47*(260), 583-621.

Levene, H. (1960). Contributions to probability and statistics. *Essays in honor of Harold Hotelling*, 278-292.

Lilliefors, H. W. (1967). On the Kolmogorov-Smirnov test for normality with mean and variance unknown. *Journal of the American statistical Association*, *62*(318), 399-402.

Loi n° 2005-102 (2005). Pour l'égalité des droits et des chances, la participation et la citoyenneté des personnes handicapées. 11 Février 2005, NOR: SANX0300217L (France).

Loi n° 2019-791 (2019). Pour une école de la confiance. 26 Juillet 2019, NOR: MENX1828765L (France).

Martínez-Monés, A., Reffay, C., Torío, J. H., & Cristóbal, J. A. M. (2017, October). Learning Analytics with Google Classroom: Exploring the possibilities. In Proceedings of the 5th International Conference on Technological Ecosystems for Enhancing Multiculturality (pp. 1-6).

Marzano, R. J., & Heflebower, T. (2011). Teaching & assessing 21st century skills. Solution Tree Press.

Mazzola, L. and Mazza, R. (2011). 'Visualizing learner models through data aggregation: a testcase', paper presented at The Red-Conference, Rethinking Education in the Knowledge Society.

Ministère de l'Éducation nationale, de la Jeunesse et des Sports - Direction générale de l'enseignement scolaire. (2016). Évaluer la maîtrise du socle commun aux cycles 2, 3 et 4. Retrieved March 18, 2021 from https://eduscol.education.fr/141/modalites–d–evaluation–des–acquis–scolaires–des–eleves .

Moss, C. M., & Brookhart, S. M. (2012). Learning targets: Helping students aim for understanding in today's lesson. ASCD.

Muñoz, M. A., & Guskey, T. R. (2015). Standards-based grading and reporting will improve education. Phi Delta Kappan, 96(7), 64-68.

Nemoto, T., & Beglar, D. (2014). Likert-scale questionnaires. In *JALT 2013 conference proceedings* (pp. 1-8).

Ochoa, X., Suthers, D., Verbert, K., & Duval, E. (2014). Analysis and reflections on the third Learning Analytics and Knowledge Conference (LAK 2013). Journal of Learning Analytics, 1(2), 5-22.

O'Connor, K. (2009). Reforming grading practices in secondary schools. Principal's Research Review, 4(1), 1-7.

Oviedo, H. C., & Arias, A. C. (2005). Aproximación al uso del coeficiente alfa de Cronbach. *Revista colombiana de psiquiatría*, *34*(4), 572-580.

Proulx, C., Spencer-May, K., & Westerberg, T. (2012). Moving to Standards-Based Grading: Lessons from Omaha. Principal Leadership, 13(4), 30-34.

Real Decreto 102/2010 (2010). Por el que se regula la ordenación de las enseñanzas acogidas al acuerdo entre el Gobierno de España y el Gobierno de Francia relativo a la doble titulación de Bachiller y de Baccalauréat en centros docentes españoles BOE-A-2010-4130 (Spain).

Rodríguez-Triana, M. J., Martínez-Monés, A., Asensio-Pérez, J. I., & Dimitriadis, Y. (2015). Scripting and monitoring meet each other: Aligning learning analytics and learning design to support teachers in orchestrating CSCL situations. British Journal of Educational Technology, 46(2), 330-343.

Schellings G, Van Hout-Wolters B (2011). Measuring strategy use with self-report instruments: theoretical and empirical considerations. Metacogn Learn 6, 83–90.

Scriffiny, P. L. (2008). Standards-based grading. Educational Leadership.

Sebesta, A. J., & Bray Speth, E. (2017). How should I study for the exam? Self-regulated learning strategies and achievement in introductory biology. CBE—Life Sciences Education, 16(2), ar30.

Slade, S., & Prinsloo, P. (2014). Student perspectives on the use of their data: Between intrusion, surveillance, and care. In Challenges for Research into Open & Distance Learning: Doing Things Better – Doing Better Things (pp. 291—300). Oxford, UK: European Distance and E-Learning Network

Soriano Rodríguez, A. M. (2015). Diseño y validación de instrumentos de medición.

Stanton JD, Neider XN, Gallegos IJ, Clark NC (2015). Differences in metacognitive regulation in introductory biology students: when prompts are not enough. CBE Life Sci Educ 14, ar15.

Stiggins, R., & Chappuis, J. (2008). Enhancing student learning. District Administration, 44(1), 42-44.

Tanner KD (2012). Promoting student metacognition. CBE Life Sci Educ 11, 113–120. Dinsmore DL, Alexander PA,

Tinto, V. (2005). College student retention: Formula for student success. Greenwood Publishing Group.

Tomlinson, C. A., & McTighe, J. (2006). Integrating differentiated instruction & understanding by design: Connecting content and kids. ASCD.

Vallance, M., & Towndrow, P. A. (2016). Pedagogic transformation, student-directed design, and computational thinking. *Pedagogies: an international journal*, *11*(3), 218-234.

Veenman MVJ (2011). Alternative assessment of strategy use with self-report instruments: a discussion. Metacogn Learn 6, 205–211.

Vescio, V., Ross, D., & Adams, A. (2008). A review of research on the impact of professional learning communities on teaching practice and student learning. *Teaching and teacher education*, *24*(1), 80-91.

Wang, M. T., Ye, F., & Degol, J. L. (2017). Who chooses STEM careers? Using a relative cognitive strength and interest model to predict careers in science, technology, engineering, and mathematics. *Journal of youth and adolescence*, *46*(8), 1805-1820.

Wise, A. F., Zhao, Y., & Hausknecht, S. N. (2013). Learning analytics for online discussions: a pedagogical model for intervention with embedded and extracted analytics. In Proceedings of the third international conference on learning analytics and knowledge (pp. 48-56).

Zimmerman BJ, Martinez-Pons M (1986). Development of a structured interview for assessing student use of self-regulated learning strategies. Am Educ Res J 23, 614–628.

Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and prospects. American Educational Research Journal, 45(1), 166–183. https://doi.org/10.3102/0002831207312909.