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Applying Learning Analytics to Map Students' Self-Regulated Learning Tactics in an Academic Writing Course

Ward PEETERS*[ab], Mohammed SAQR[c] & Olga VIBERG[d]
[a]*Kanda University of International Studies, Japan*
[b] *University of Antwerp, Belgium*
[c] *University of Eastern Finland, Finland*
[d] *KTH Royal Institute of Technology, Sweden*
*peeters-w@kanda.kuis.ac.jp

Abstract: Academic writing is a complex and challenging language learning activity, in which self-regulation is a key critical factor for learner success. Today, a large number of academic writing activities occur in digital learning spaces, including computer-supported collaborative learning settings. Recent advances in the fields of learning analytics (LA) and computer-assisted language learning have provided new opportunities, in part because of the accessibility to new digital learner data, to better understand and ultimately support students' self-regulated learning (SRL) processes. Even though some related efforts have been made, there is yet a paucity of research targeting foreign language students' interactive SRL behaviour in online environments. This study aims to shed more light on this issue, and on the possible ways to fill this gap. We used LA methods (frequency analysis, network analysis, statistical analysis and process mining) to analyse and visualise students' SRL tactics when collaborating with their peers on academic writing tasks on social networking sites. The dataset was obtained from a case study performed at the University of Antwerp (Belgium). In this study, a private Facebook group was integrated in an academic writing course for first-year foreign language majors of English (n=124) and served as an online collaborative space for peer review. The results show, firstly, that foreign language learners use a range of SRL tactics to manage their academic writing process and, secondly, that the strategic SRL task phases (i.e., plan, perform and evaluate) are strongly interconnected. Learners exhibit a readiness and willingness to activate knowledge, monitor progress, interact to adjust to the socio-cultural context and form an identity as a learner. There is a significant positive correlation between students' use of SRL tactics and their learning performance, which provides novel ground for designing and providing relevant SRL support mechanisms in computer-supported collaborative learning.

Keywords: Academic writing, social networking sites, self-regulated learning, learning analytics, higher education

1. Introduction

In recent years, the fields of computer-assisted language learning (CALL) and self-regulated learning (SRL) have grown closer with an increased interest in the application of data-driven methods to study language learners' self-regulatory learning processes in online learning settings (Li, Flanagan, Konomi, & Ogata, 2018). Significant attention has been paid to how online spaces can foster, among others, language learner autonomy, self-regulation and a range of productive skills like writing and speaking in second language learning (Montrul, 2019; Peeters & Ludwig, 2017; Viberg, Mavroudi, & Ma, 2020). In her review of social networks for language learning beyond the classroom, Zourou (2019) emphasises that Web 2.0 platforms and social networking sites (SNSs) have taken a ubiquitous role in this regard because they have offered educators and researchers new opportunities to foster both formal and informal learning in their daily practice, and have given them access to new types of learner data. The use of SNSs provides an opportunity to balance "the learning benefits from emergent user-driven agency of everyday use with the demands to meet formal curriculum-driven objectives" (Reinhardt, 2017, p.1), and thus forms a sound testing ground for transferable SRL skills in collaborative learning

settings. This study focuses on academic writing as it is one of the major skills second language learners need to acquire to achieve their learning goals. Academic writing is also one of the skills learners have been observed to struggle most with when entering university, and thus for which they require ample SRL skills (Van de Poel & Gasiorek, 2012). However, in the field of CALL, little research has been conducted on learners' interactive behaviour in online spaces or SNSs (Peeters, 2019), let alone how interactive behaviour in digital text relates to SRL strategies and tactics for academic writing.

Recently, a growing shift to measure students' SRL behaviours using student trace log data and multimodal learner data has been kindled by the increasing interest in learning analytics (LA; Viberg, Khalil, & Baars, 2020). The application of LA methods allows scholars to study multifaceted aspects of students' SRL and, based on these measurements, to offer relevant learner support and optimisation of SRL and the contexts in which it occurs. This study employs LA methods to analyse students' SRL activities or tactics (i.e., the specific, applied way/s in which a strategy is being used to meet a goal in a certain situation; Oxford, 2016) when collaborating with their peers on academic writing tasks on SNSs in order to reveal how learners use such tactics to optimise their learning. The following research questions have been posed:

1) How do foreign language learners use self-regulatory tactics to manage their academic writing process?

2) How do high and low performing learners use self-regulatory tactics?

2. Background

2.1 Academic Writing and Self-Regulation

Academic writing serves several academic objectives such as promoting critical thinking skills, stimulating creativity, and encouraging discourse as part of a professional community (Hamman, 2005). Consequently, students' ability to present information and ideas through their writing has "an integral role in academic and professional success" (Applebee et al., 1994, p. 25). Academic writing is a complex and demanding learning activity, in which self-regulation and self-efficacy are critical factors for learner success (Golombek, Klingsieck, & Scharlau, 2019). Self-regulation in writing refers to the "self-initiated thoughts, feelings, and actions that writers use to attain various literary goals, including their writing skills as well as enhancing the quality of the text they create" (Zimmerman & Risemberg, 1997, p.76). When writing in an academic context, learners have to "negotiate rules and mechanisms while maintaining a focus on the overall organisation, form and features, purposes and goals, and audience needs" (Harris et al., 2002, p.110). In such an undertaking, learners employ various SRL strategies and tactics to regulate the complex writing process (Zimmerman & Risemberg, 1997). The importance of fostering SRL strategies and skills among learners, and among foreign language learners in particular, have been stressed by scholars (see e.g., Abadikhah, Aliyan, & Talebi, 2018; Csizer & Tanko, 2015). Also, earlier research indicates that there is a correlation between students' self-regulation of writing and learning performance. Zimmerman and Bandura (1994) for example, found that students' perceived self-efficacy beliefs in academic achievement and self-regulation of writing could predict their final writing course grade.

2.2 Learning Analytics and Self-Regulated Learning

LA is a growing area of practice and research, focusing on the improvement of student learning outcomes and the improvement of learner support (e.g., support for the development of learner skills such as SRL skills, e.g., goal setting and effort regulation) and teaching (Ferguson & Clow, 2017). One of the emerging subfields that LA researchers target is self-regulated learning (SRL; see Viberg et al., 2020). SRL –which consists of "the processes whereby students activate and sustain cognitions, affects, and behaviors that are systematically oriented toward the attainment of personal goals [i.e., to succeed in academic writing in our study]" (Zimmerman & Schunk, 2011, p.1)– has been found to be critical for second language learners (Oxford, 2016; Viberg & Andersson, 2019; Viberg, Mavroudi, & Ma, 2020) and also for the learner success in academic writing (e.g., Rapp & Ott, 2017).

LA for SRL consists of two constituting parts: 1) a description of student SRL activities, based on traces of actions performed during study (i.e., measurement), and 2) a recommendation, i.e., what should be changed about how learning activities are performed, and instructions about how to change them in order to better achieve learning goals (Winne, 2017). This study mainly focuses on the potential of LA to understand student SRL in a computer-supported collaborative writing setting. The findings of the analysis aim to provide a sound ground for relevant recommendations to improve learner SRL support in the chosen learning settings. Earlier LA research on writing analytics have shown promise of how LA can support academic writing. Notable is the work on the Academic Writing Analytics (AWA) web app, the results of which showed how the provision of actionable feedback helped students improve their writing skills (Gibson et al., 2017). Similarly, within the frames of the same AWA project, an LA tool (AcaWriter) offered students personalised feedback on their writing (Knight et al., 2020). Others have also shown the value of using automatic detection of meta-discourse to support academic writing (Bektih, 2017). However, research on self-regulation and academic writing remains scarce and this study aims to further inquire into this issue to fill this gap.

2.3 Theoretical Lens of Self-Regulated Learning

To understand students' SRL tactics in computer-supported collaborative writing settings, and in particular, to categorise them according to the SRL phases, the theoretical lens of the Strategic Self-Regulation (S2R) Model of language learning (Oxford, 2016) has been adopted. In general, the S2R model targets meta-strategies, strategies and tactics that language learners can use to regulate various aspects of their learning, including beliefs, observable behaviours, their internal mental states, as well as the learning environment. The model includes a sequence of phases for doing a task (Figure 1). In task-phase 1, *strategic forethought*, the learner pays attention to the demands of the task, goals, plans how to address them, and activates them. In the second phase, *strategic performance*, the learner implements the plan, monitors how it is working, and decides whether to continue the task as it is going, stop, or make changes in how to approach the task. In the third phase, *strategic reflection and evaluation*, the learner makes judgements of value about learning outcomes, the effectiveness of selected strategies and tactics, and the self (e.g., self-efficacy).

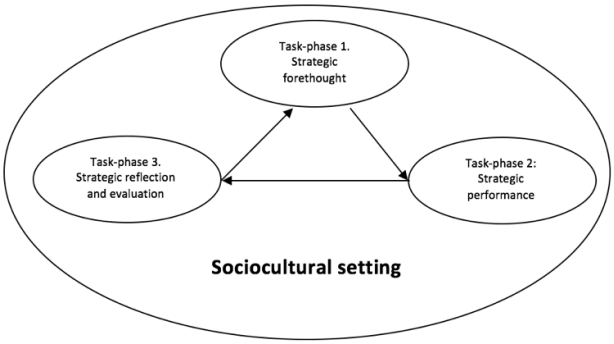

Figure 1. Strategic self-regulation task-phase model of language learning (Oxford, 2016).

As mentioned above, the S2R model includes not only meta-strategies and strategies, but also *tactics*, which are focused on in this study. Tactics refer to more specific manifestations of a strategy and meta-strategy by a particular learner in a given learning setting for a specific purpose. They denote the specific, applied way/s in which a strategy is being used to meet a goal in a certain situation.

2.4 Case Study Settings

The dataset used in this paper was obtained from a case study performed at the University of Antwerp (Belgium). In this study, a private Facebook group was integrated in an academic writing course for first-year foreign language majors of English (n=124) and served as an online collaboration space for peer review in which they could share their written work, discuss their progress and ask questions about their writing and learning process. The course consisted of 12 contact hours, blended with an online self-access module with exercises on academic literacy, and the peer review forum on Facebook. No

teachers were included in the Facebook group. Learners had to rely on their peers for support (Murray, 2014). Over a period of three months, learners had to write three 300-word essays. After an initial brainstorm in class, learners had to finish their essays at home and were informed that they could consult with their peers on Facebook about their writing process and the challenges they faced.

3. Methods

In the initial stages, the data set was manually coded using the principles of digital conversation analysis to distinguish recurring patterns in the structure and content of status updates and comments (cf. Farina, 2018). In several data-driven coding phases (cf. DeCuir-Gunby, Marshall, & McCulloch, 2011), a team of two coders compiled a taxonomy of core activities in the data sets (Peeters, 2018), after which a team of four coders checked the coded transcripts. The team reconciled to discuss coding errors and inter-rater reliability. Disputed codes were further discussed and amended until a consensus was reached on all the codes in the transcripts. The taxonomy presented below (Table 1) was used as the basis for this study into students' SRL activities in an academic writing course. The table includes the topics and tactics students addressed (adapted from Oxford's (2016) cognitive, affective and sociocultural-interactive activities), representing the task-phases in the S2R model (Figure 1).

Table 1. *Overview of Tactics and S2R task phases in the data set*

Tactics representing task-phases in the S2R Model	Short label	SRL Task Phase
Students sharing stories, tips and tricks about academic, cultural, social, psychological and linguistic challenges they face.	**Acculturating**	Strategic forethought
Students planning the next steps in their writing or learning trajectory and implementing those plans.	**Planning**	
Students discussing and familiarising themselves with goals, objectives and requirements of the course and tasks.	**Organising**	
Students discussing vocabulary, jargon, grammar and textual structure while writing essays.	**Writing text**	Strategic performance
Students discussing topics / thesis statements for their essays, and discussing reasoning and logic of their (counter-)arguments.	**Argumenting**	
Students sharing, discussing and evaluating resources provided by the university and by the peer group.	**Using resources**	
Students talking about hobbies, free time and leisure.	**Social bonding**	
Students expressing positive feelings towards their peers, acknowledging their work and thanking them.	**Acknowledging**	
Students discussing and applying feedback they received from the teacher or from their peers.	**Feedback**	
Students discussing the purpose and organisation of the course, the tasks and the collaboration between peers.	**Reflecting**	Strategic reflection and evaluation

Learners received grades through continuous assessment throughout the semester. The essay-writing task added up to 30% of the overall grade for the course, next to in-class tests and assignments, as well as self-access exercises online. Learners' overall grades are compared to their interactive behaviour online to study if high-performing learners use different SRL tactics compared to low-performing learners in academic writing. Previous research in process mining and analysis of SRL strategies has shown that the comparison of deciles helps show the differences or similarities between subgroups in how they implement learning strategies or tactics (Saint, Gašević, Matcha, Uzir, & Pardo, 2020; Saqr et al., 2019). We accessed the scores on the three essay-writing tasks and compiled a composite score. The top decile was identified as the top 10 percent performing students, the bottom decile was identified as the bottom 10 percent performing students.

3.1 Data Extraction

A Graph API Explorer tool was used to scrape and compile the dataset. The dataset, consisting of 2594 entries, includes IDs for every participant, status updates and comments, post IDs for every entry and time stamps. The data set has been anonymised before any analysis was conducted. Since some posts were coded with two tactics, the final count was 3123.

3.2 Analysis

To answer the research questions and reveal the multifaceted nature of self-regulated academic writing, multiple analytical lenses were used. We implemented four analytical methods: 1) frequency analysis, 2) network analysis, 3) statistical analysis, and 4) process mining. They have been employed to highlight different aspects of students' tactics and their correlation with students' performance. For RQ1 the four methods were used to reveal different tactics and how they correlate to each other. For RQ2, we present a comparison between the high and low performers. Frequency analysis was conducted to demonstrate the distribution of tactics among learners (RQ1) and to report the differences and similarities between learners' subgroups (RQ2). Frequency analysis was conducted with the *R* programming language. Statistical analysis was performed to investigate the correlation between the employed tactics and students' performance (RQ2), with the aim to highlight frequent tactics that could serve as indicators of favourable course outcomes. The correlation was performed using *R* and Spearman's rank correlation coefficient since the grades were not normally distributed, as examined by the Kolmogorov-Smirnov and the Shapiro-Wilk tests of normality. Process mining was implemented for determining and visualising the processes of the students' interactive behaviour and tactics.

Two types of process mining approaches were applied. Firstly, relative frequency-based process mining offered by the R package BupaR was used (Janssenswillen, Depaire, Swennen, Jans, & Vanhoof, 2019). Bupar packages offer sequential process maps that highlight the flow and frequencies of examined tactics. To construct the process maps, the timestamp of each student interaction was used as the event time; the coded tactic was used as the 'event' and the students' IDs as the case IDs. The node metrics of the process map represent the relative frequency of the implemented tactic; the edges represent the associative internode relative frequencies (RQ1). Secondly, stochastic process mining was performed using the R package PMineR to explore the associative probabilities of students' tactics (Gatta et al., 2017). PMineR offers methods for the calculation and visualisation of First Order Markov Models (FOMMs). FOMM computes the probability that a current learner tactic depends on the previously employed tactic known as the transition probability (TP). TP is reflected in the FOMM models through the width of the edges between the FOMM nodes. The FOMM graphs were generated for the whole learner group (RQ1), and to compare the top vs the bottom deciles (RQ2). A directed network was constructed by considering the reply of a post as source, and the replied to post as target (RQ1). For each tactic, we calculated degree centrality as the number of interactions for the tactic (incoming and outgoing), betweenness centrality as the number of times a tactic has lied on the shortest path between others, thus connecting them; closeness centrality as the inverse distance between a tactic and all others, diffusion centrality as the probability that tactics propagate/stimulate further interactions.

4. Results

The frequency of the tactics used by learners (Figure 2) shows that posts and comments that addressed issues with writing text (16.8%) and constructing argumentation (16.1%) for essays took up a considerable part of the peer review process. Given the nature of the assignments and the educational context, this was expected. Providing acknowledgement (20.6%), which includes expressing positive feelings towards peers, acknowledging their work and thanking them, was also very prominent. These three tactics are part of the strategic performance phase in the S2R model (Oxford, 2016). Other tactics in this phase, in decreasing order of frequency, could be found in posts and comments that revolved around social bonding (8.3%), applying feedback (7.2%) and using resources (6.1%). Acculturating to the academic context (9.9%), which concerns discussions between peers about the challenging transition from their previous scholarly experiences towards a university's academic culture (Peeters &

Fourie, 2016), was the most prominent tactic when it comes to strategic forethought. Tactics in which students familiarise themselves with the goals, objectives and requirements of the course and tasks (9.4%) came in as a close second. Planning (0.4%), on the other hand, was a tactic seldom used by students in their conversations with others. Within strategic reflection and evaluation, students reflected on their performance (5.3%), yet less frequently than other tactics. students predominantly engaged in the performance phase while also paying attention to the demands of the task, set goals, plan how to address them, and activate existing knowledge.

Operationalising the interactions as a network of tactics shows how interactions were built, and which tactics were well-connected or central (Figure 2). Expectedly, writing text and arguments were the most prominent central tactics in terms of quantity (Table 2). However, acculturating and organising were the tactics that were most likely to connect to other tactics (high betweenness centrality degree). Acculturating, acknowledging, reflecting and social bonding were the tactics close to all other tactics. Using diffusion metrics to discover which tactics were more likely to propagate or stimulate further discussions, we see that almost all tactics were well connected, but that acculturating, acknowledging, reflecting and social bonding, again, were the tactics that were the most central. Notably interesting are the tactics with a 0 score for betweenness centrality: acknowledging, applying feedback and writing arguments, indicating that these tactics were less connected to other tactics or were predominantly used to conclude or end a conversation.

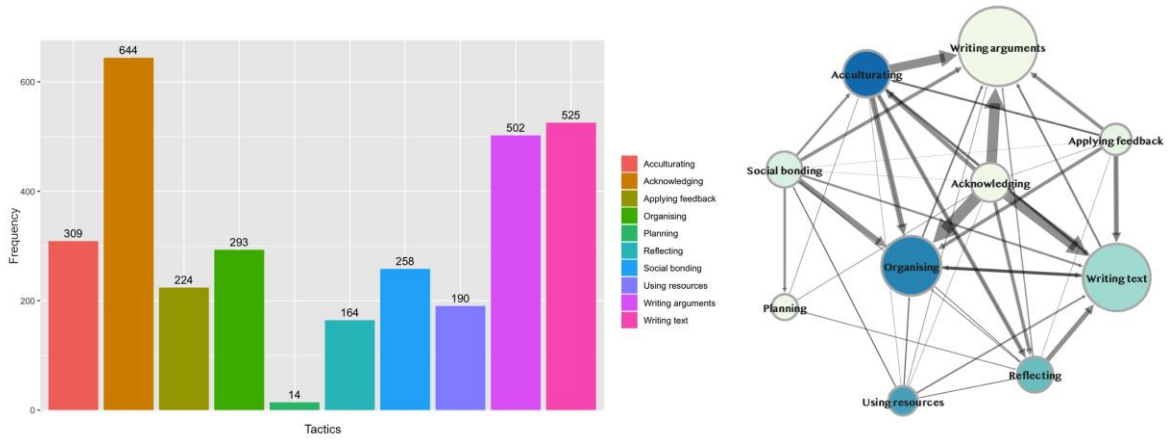

Figure 2. Summary of tactics in the peer interaction process on academic writing (left) and network of students' SRL tactics (right). The nodes represent different tactics while the directed edges represent the degree of connection between them.

Table 2. *Centrality Degree Scores of Students' SRL Tactics*

Tactics	Degree	Closeness	Betweenness	Diffusion
Acculturating	0.46	1.00	0.13	1.00
Acknowledging	0.37	1.00	0.00	1.00
Applying feedback	0.10	0.49	0.00	0.96
Organising	0.63	0.72	0.12	0.99
Planning	0.01	0.01	0.00	0.01
Reflecting	0.22	1.00	0.08	1.00
Social bonding	0.28	1.00	0.01	1.00
Using resources	0.07	0.49	0.10	0.95
Writing arguments	1.00	0.72	0.00	0.99
Writing text	0.94	0.72	0.05	0.99

A correlation matrix was generated between tactics and students' performance (Figure 3). There was a positive and significant correlation between the assignment grades and the frequency of 1. acculturating (r_s=0.27, p<.01), 2. acknowledging (r_s=0.19, p<.05), 3. organising, (r_s=0.3, p<.01), 4. writing arguments (r_s=0.22, p<.05), 5. writing text (r_s=0.38, p<.01), and the total number of interactions with peers regardless of the type (r_s= 0.29, p<.01). The correlation coefficient results also show which tactics were correlated. The highest correlated pairs were: 1. organising and acknowledging (r_s=0.6, p<.01), 2. organising and acculturating (r_s=0.56, p<.01), 3. reflecting and social bonding (r_s=0.55, p<.01), 4.

acculturating and writing arguments (r_s=0.54, p<.01) as well as 5. reflecting and acculturating (r_s=0.53, p<.01). These results also stress the importance of the tactics of writing text, argumentation and acculturating as indicators of success in academic writing, as well as in kindling other successful tactics.

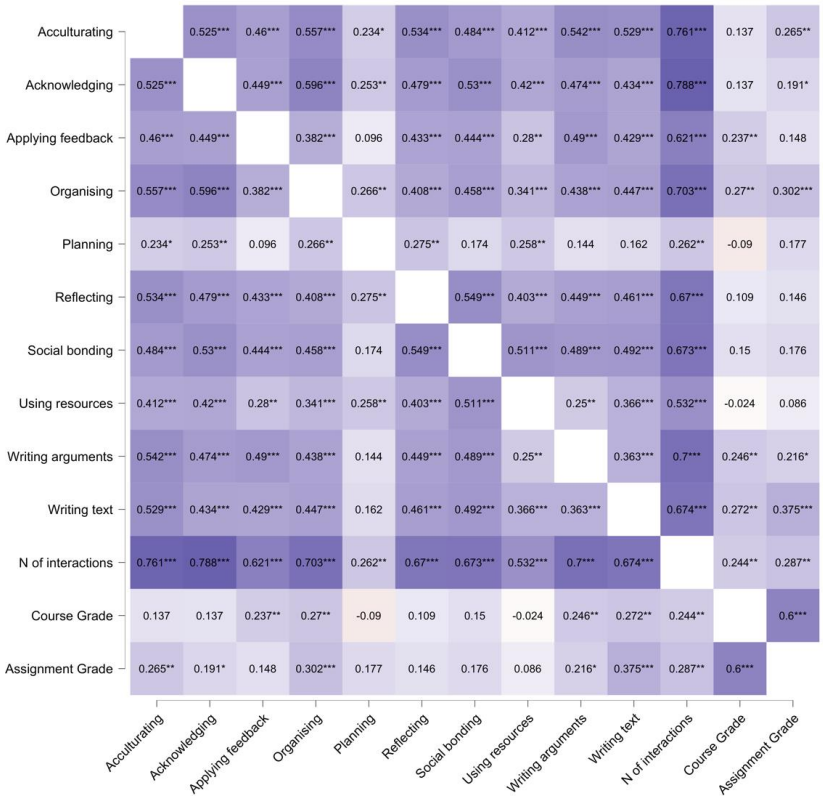

Figure 3. Correlation matrix between students' use of tactics and students' performance.

A closer look at the sequential process map of students' SRL may explain the sequential process of the discussions (Figure 4). Students are likely to start with composing argumentation for essays (54.5%), composing text (29.4%) or sharing questions and thoughts on the academic context they have to function in (10.1%). Acknowledging is the step that most frequently follows other steps in this process, often followed by other acknowledgements (54.3%). Similarly, steps that involve writing arguments are often followed by steps that address argumentation (45.2%). Writing text also has this feedback loop (40.4%). The frequency-based graphical mapping shows a general map of the process. Yet, it is limited in making inferences about the likelihood of transitions. Hence, FOMM graphs are necessary.

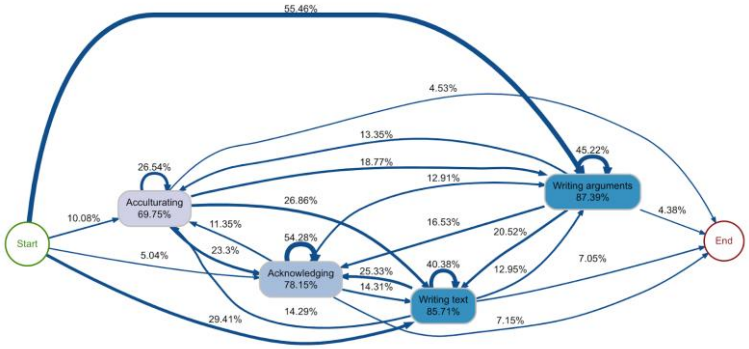

Figure 4. Sequential process map of students' SRL tactics

The FOMM graphs (Figure 5) show a more diverse range of starting points for sessions of interactions, with the highest likelihood of starting with writing text (0.37), followed by writing arguments (0.2), or organising and acculturating with both a 0.12 probability. Acknowledging is a common transition step to follow other steps with higher probability than other tactics. Similarly, writing text acts as a common

transition step after reflection, writing arguments, organising and acculturation. This mapping reflects a diverse approach to SRL with a set of prominent steps that seem to be central in the interaction process.

Figure 5. First order Markov Model of students' SRL tactics.

In order to answer the second research question and analyse whether the top and bottom decile act differently, FOMM graphs for the two groups were created (Figure 6). The results show that top achievers are more likely to initiate a conversation by using the tactic of writing text (0.5) compared to bottom achievers (0.31). Bottom achievers also are more likely to use a range of different tactics to start a conversation, including using resources (0.23), acculturating (0.23) and organising (0.13) in addition to writing. Top achievers are more likely to address issues with writing arguments (0.17) and organising (0.17) at the beginning of a conversation. Both groups are likely to acknowledge others as a follow-up step in the interaction process.

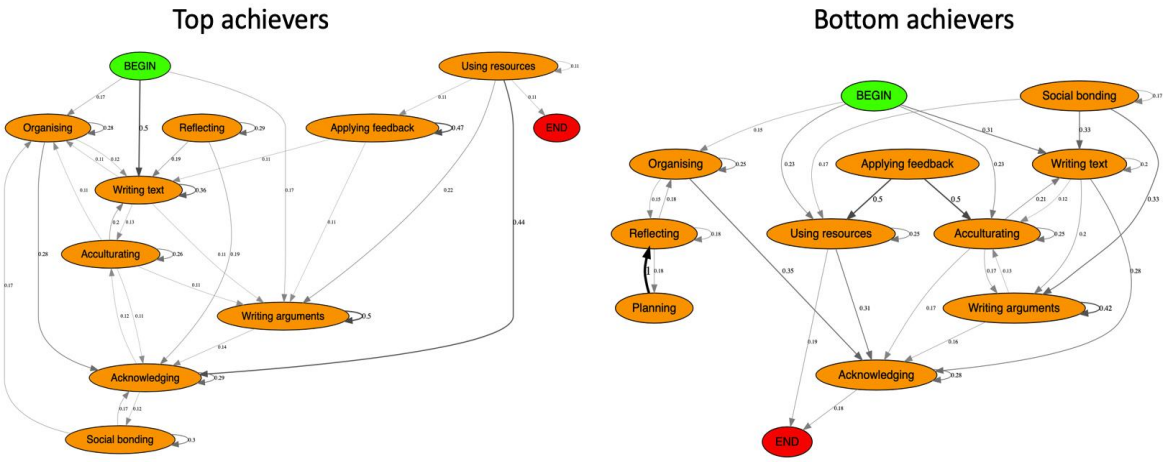

Figure 6: First Order Markov Model of top and bottom achievers' SRL tactics

5. Discussion & Conclusions

This study aimed to analyse how foreign language learners' interactive behaviour in digital text relate to their SRL tactics in an academic writing course. The findings of this study exhibit that foreign language learners use a range of SRL tactics to manage their academic writing process. Composing text and argumentation –which represent the strategic performance phase of the S2R model (Oxford, 2016)– are frequently used tactics and from the results of our sequential process mapping, we found that these tactics are often used as conversation starters. Correlation coefficient findings also show that certain tactics are highly correlated. Most notably, correlations between organising (a part of the strategic forethought phase) and acknowledging (the strategic performance phase) indicate that students often express positive feelings towards each other in their discussions on how to deal with the course, its tasks

and its requirements. Organising and acculturating are also linked, which suggests that discussing goals, objectives and requirements (the strategic forethought phase) often go hand in hand with adjusting to the broader sociocultural context of academia. Reflecting and social bonding correlate as well. This exhibit that reflections might often coincide with telling personal stories and self-disclosure. In addition, the network analysis has shown the prominence and interconnectivity of tactics like acculturating, acknowledging, reflecting and social bonding within a wide range of interactions. These findings demonstrate to what extent the S2R task phases are interconnected, and how learners can orchestrate them, with room for activating knowledge, monitoring progress, interacting to adjust to the socio-cultural context and forming an identity as a learner.

To answer the second research question, we analysed if high-performing learners used different SRL tactics compared to low-performing ones. The results have shown that students who paid special attention to the form and/or content of their writing, as well as the ones who acknowledged others during discussions, scored higher marks than those who did not. Those who engaged in the strategic forethought phase of academic acculturation and organisation, i.e., negotiation context (cf. Harris et al., 2002), also performed significantly better. Similarly, students who discussed how to apply feedback from peers or tutors were more likely to score higher final course grades.

A positive and statistically significant correlation was found between the final course grades and writing text, writing arguments, and discussing goals, objectives and requirements of the course and tasks. The FOMMs comparing high and low achieving students echo these findings and additionally show how the top decile is more likely to initiate conversation using tactics from the strategic performance phase: writing text and arguments. The bottom decile uses a wider range of tactics like using resources, acculturating and organising as well as writing text when starting a conversation. While both groups make use of tactics that represent strategic forethought, the top decile is more likely to dive head first in the actual writing process when interacting with their peers. It has to be noted that both groups rarely discuss planning, and that the top decile even tends to skip this tactic altogether.

In summary, this study has offered a solid example of how students' SRL tactics can be effectively traced with the help of LA methods. To obtain a more holistic picture of the students' SRL process, the next step will be to examine how these tactics are linked to other constructs (i.e., SRL strategies and meta-strategies) and dimensions (i.e., cognitive, affective and socio-cultural interactive) of the used S2R model (Oxford, 2016). This will offer a more sound ground for designing and providing relevant SRL support mechanisms, for example in a form of student-facing learning dashboards (Viberg et al., 2020). Such dashboards can also be oriented towards teachers for the purpose of enabling them to teach relevant SRL strategies and intervene in time.

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