

Assessing the Effectiveness of Self-Regulated Learning in MOOCs using Macro-level Behavioural Sequence Data

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Abstract. Learners are demanded more self-regulatory capability to carry on effective online learning. Online course instructors attempt to stimulate online learners' effective self-regulated learning (SRL) to support effective learning and enhance achievement. Knowing how the online learners learn in SRL loop will contribute to the effective course design and scaffolding. In this study, the learners from an edX MOOC were differentiated into more effective self-regulated learners (SRLers) and less effective SRLers based on the criteria of three SRL phases behavioural sequence patterns. The clickstream data of 5764 learners was analyzed on macro-level behavioural learning sequence through n-gram algorithm. Persistence and grade were compared among the different types of learners. The results showed us that more effective SRLers persisted longer and performed better than less effective SRLers on a significant level.

Keywords: Self-regulated Learning, Behavioural Sequence Pattern, MOOC, Persistence, Learning Achievement

1 Introduction

Recently, massive open online courses (MOOCs) offer people more opportunities to access the free educational resources. Learners are required more self-regulation capability to self-learning with fewer instructors' assistance. Various emerging problems on learning and teaching in MOOCs challenge the MOOCs development. For instance, the prominent high attrition phenomenon [1] leads the persistence issue to become one of the controversial topics for MOOC study. According to Wigfield, Klauda, and Cambria [2], persistence is a key behavioural indicator of self-regulatory capacity in the monitoring and control phases of self-regulation. Most previous persistence research in SRL field was conducted in face to face situation using a self-reported questionnaire or experiment [3-4]. In some e-learning settings, for instance, Azevedo and his colleagues [5] developed a tool named Metatutor to assess and convey SRL. These studies suggested that the adaptive scaffolding based on learners' navigation path was necessary to fostering learners' learning and use of key SRL processes. However, these fine-grained scaffoldings stressed on time-sensitivity that remains a challenge for researchers [5], because micro-level click actions from whole course learning behaviour perspectives generated uncountable learners' types, which are inapplicable for scaffolding from SRL aspects. When it comes to the natural learning processes in the online environment, to accurately detect, track, and model students' SRL processes will remain a challenge as well [6-7]. In this study, through

exploring the clickstream data in an edX MOOC, based on the edX platform feature and course design feature, the learning processes were detected to see how the SRL behavioural sequences patterns reflect persistence and achievement.

2 Related Work

Studies show that self-regulatory processes are different among students and the differences lead to the variance in achievement [8-9]. Schunk [10-11] states that self-regulated learning (SRL) is an effective means to improve achievement. According to self-regulated learning theory, students are self-regulated to the degree they are metacognitively, motivationally, and behaviorally active participants in their learning processes [12]. These metacognitive processes include goal setting, self-monitoring, and self-evaluative feedback loops. Motivational feelings and beliefs refer to self-regulated learners' display of personal initiative, perseverance, and adaptive skills. Researchers may be unable to observe the learners' psychological states or cognitive thinking. However, behaviorally, self-regulation refers to specific beneficial actions, such as record keeping, environmental structuring, and help-seeking, which are observable [12].

In traditional studies, SRL measuring included self-reported questionnaires, structured interviews, teacher ratings, think aloud methods, error detection tasks, trace methodologies, and observations [13]. Questionnaires and interviews are two most widely-used measurements in MOOC studies on SRL topics. Kizilcec et al.'s studies [3-4] provided us with some implications of how learners perform in MOOC context, but, in terms of research method, as Winne and Perry [13] indicated, self-report measures do not necessarily give a reliable picture of the self-regulation tactics students actually engage in.

The fine-grained log data that were recorded by online platform give a chance to apply trace methodology and learning analytics on every or groups of participants. In a MOOC video study, researchers suggested that the clickstream data organized by using n-gram algorithm method may help people understand how the online learners process information [14]. According to topic modeling and n-gram analysis, researchers construct the behavioural actions sequences into several categories to classify how these learners interact with the online videos and process information [14]. However, viewing learners' behaviours as a whole, their online actions on other pages or activities also reflect their cognitive thinking. Moreover, instructional designers promise that learners who follow an underlying SRL behavioural sequence pattern may have a better learning achievement. We assume that the more effective SRL learners would have a relatively regular macro-level learning sequence. In other words, when the actual online learning behaviours are calibrated with or similar to the ideal learning sequences, they may get on the right track of SRL loop and learn better and longer in an online course.

According to social cognitive SRL model from Zimmerman [15], the three-stage learning process consist of forethought and planning phase, performance monitoring phase and self-reflection phase. The more effective SRLers who experience the complete three-stage loop are assumed to learn better than those who do not

experience the completed SRL loop. From this perspective, we can distinguish effective form from ineffective forms self-regulation from the quality and quantity of one's self-regulatory behavioural sequence processes [15].

3 Research Questions

1. What types of learners do we have in MOOC based on macro-level SRL behavioural sequence patterns?
2. What is the relationship between the macro-level SRL behavioural sequences and persistence in MOOC?
3. What is the relationship between the macro-level SRL behavioural sequences and grade in MOOC?

4 Method

4.1 Course Context

The MOOC, *Epidemics*, offered by The University of Hong Kong on edX was used in this study. It composed of ten weeks of learning materials that were broken up into four themes. There were 4-10 video lectures in each week (most videos were 5-10 minutes). Quiz was the only assessment in this MOOC. According to the navigational bar, this MOOC has five blocks: Home (H), Course (C), Course Details (CD), Discussion (D) and Progress (P). The learners' click action on each block will create one macro-level behaviour record. Under Course block, as the video watching and quiz taking are two main activities, they are also defined as two macro-level activities.

4.2 Data Collection

Data Cleaning

Raw data were collected from 5764 learners who did at least one action in this MOOC during the first running time. It was organized based on three items: user id code, time, and event. Non-learners' behaviour records (e.g. system self-generated records and instructors' records) were removed. Then, the micro-level behaviours were clustered into a macro-level behaviour if the same macro-level behaviour category was in a linear sequence based on the time series. For instance, in a time duration 07:00:00 to 07:20:00, all the micro-level behaviours for doing the quiz that included the actions of saving the answer, checking the answer and showing the correct answer were marked as "Q". Table 1 illustrates the ID-based macro-level behaviour sequence list.

Table 1. Learner macro-level behaviour sequence list

ID	Learning Sequence
3465	H C D C V D C H V C D D C V C V Q C V
5317	H C D D P C V C V C V Q C V
5879	H C V C V C V Q V Q V C Q C V Q C V Q V Q V Q C V C V H P H C D C H C V C V C ...

Data Analysis

In this study, the n-gram is the contiguous sequence of n items from a learner’s online learning clickstream record on the macro-level behaviours. For instance, the behavioural sequences “H-CD-C-V-Q-D-P” would be composed of 2-grams (e.g. H-CD, CD-C, C-V, V-Q, Q-D, D-P), 3-grams (e.g. H-CD-C, CD-C-V, C-V-Q, V-Q-D, Q-D-P) and 4-grams (e.g. H-CD-C-V, CD-C-V-Q, C-V-Q-D, V-Q-D-P).

Researchers predict some sequences that may reflect the SRL behaviours. During the forethought phase, learners prepare work before performance phase on their studying [15]. **In an online setting, any navigational button that provides the course information may attract learners’ attention to preview/overview the course as a pre-action.** In this study, Course details (CD) offers the information about the course learning outcomes, course syllabus, course assessing types and grade criteria, which the learners may go through before doing activities in the performance phase. In performance phase, self-control and self-monitoring occur in the learning process that involves learner’s attention and willpower [15]. **In the relatively fixed online setting, the behaviours in performance phase mainly happen during the activities.** The activities are mainly in the Course page (C), which include video lecture (V), quiz (Q), and discussion (D). Learners carried out different task strategies to monitor their learning process. Many reasonable sequences patterns can be the combination of C, V, Q and D. Self-reflection phase happens in the final stage when learners review their performance toward final goals [15-16]. **Any course design that helps learners review their performance or match to the final goals can be potentially lead to actions in self-reflection phase.** Progress page (P) helps the learners check their learning progress is going on. Since the quiz is the only assessment in this course, a possible self-reflection behavioural sequence pattern may be the Q-P and V-Q-P or Q-P-CD because after taking the quiz the learner may review their performance on P. Above all, three SRL behavioural sequence patterns were proposed in Table 2. Each learner will have a count record of sequence pattern in each of the three SRL phases. More effective SRLers are those who did action in each SRL phase, while less effective SRLers may missed one or two phases.

Persistence is defined as the weeks the learner stays in the course (10 weeks in total). Achievement is the grade (1 point in total). One-way ANOVA will be conducted to observe the significant differences among the more effective SRLers and less effective SRLers on persistence and achievement. In the relationship between the persistence/the grade and three SRL phases, multiple regression will be applied.

Table 2. Three SRL Behavioural Sequence Patterns

Phase	Sequences
Forethought Phase	H-CD, CD-C, H-CD-C, H-C-CD-D-P (or H-CD-D-P-C or C-H-CD-D-P)
Performance Phase	C-V, V-Q, C-V-Q, C-D, V-D, C-V-D, Q-D, C-Q-D, V-Q-D, C-V-Q-D
Self-reflection Phase	P-CD, Q-P, Q-P-CD, V-Q-P, V-Q-P-CD

5 Result

5.1 Macro-level SRL Behavioural Sequences Overview (RQ1)

According to the definitions of more effective SRLer and less effective SRLer mentioned above, it is found that the number of less effective-SRLers was nearly four times of that of more effective SRLers (See Figure 1).

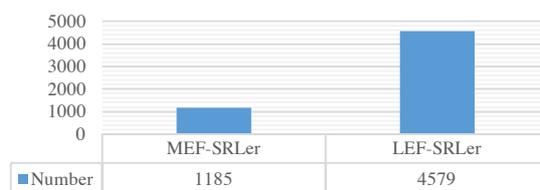
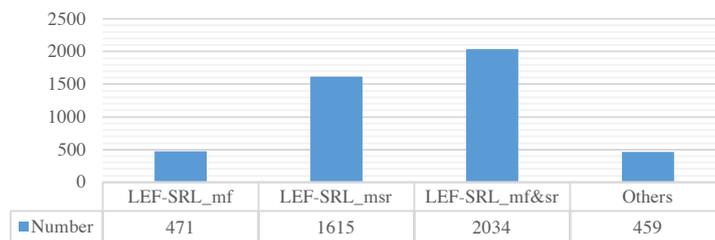


Fig. 1. Number of More Effective-SRLers (MEF-SRLer) and Less Effective-SRLers (LEF-SRLer) (N=5764)

The less effective SRLers were further subdivided based on the phase(s) they missed (See Figure 2). About 45% less effective SRLers missed both the forethought and self-reflection phases, and around 10% and 35% less effective SRLers missed forethought phase and self-reflection phase respectively. There were even about 10% less effective SRLers missed the performance phase based on the SRL behaviours criteria. These learners are regarded as browsers (“Others” in the figure).



*LEF-SRL_mf: only miss forethought phase; LEF-SRL_msr: only miss self-reflection phase; LEF-SRL_mf&sr: miss forethought phase and self-reflection phase; Others: those who assess to the course but may never do any course-related activities

Fig. 2. Types of less effective SRLers (LEF-SRLers)

5.2 Persistence and SRL Behavioural Sequence Patterns (RQ2)

As shown in Table 3, more effective SRLers had the highest mean value of persistence and others had the lowest. With the one/two SRL phase(s) missing, the persistence decreases. Especially when the self-reflection phase was missing, the persistence accelerated dropped slightly. One-way ANOVA analysis and Tukey test showed that the persistence of the different types of learners was different significantly ($F = 886.146$, $p\text{-value} < 0.001^{***}$).

Table 3. Persistence and More Effective-SRLers (MEF-SRLer) and Less Effective-SRLers (LEF-SRLer)

<i>Persistence</i>	MEF-SRLer (n=1185)	LEF-SRL_mf (n=471)	LEF-SRL_msr (n=1615)	LEF-SRL_mf&sr (n=2034)	Others (n=459)
<i>Mean</i>	6.528	5.461	2.975	2.197	1.242
<i>Std</i>	2.966	3.000	2.384	1.816	0.684
<i>Min</i>	1	1	1	1	1
<i>25%</i>	4	3	1	1	1
<i>50%</i>	7	5	2	2	1
<i>75%</i>	9	8	4	3	1
<i>Max</i>	10	10	10	10	9

We found that forethought phase and performance phase had a small positive effect on persistence through ordinary least square (OLS) multiple regression, but they all reached the significant level on statistics [Adj. R^2 (0.480), Prob (F-statistics < 0.001), the coefficients of the three independent values (β -forethought = 0.0482, $\rho < 0.01^{**}$, β -performance = 0.0170, $\rho < 0.01^{**}$, β -reflection = -0.0008, $\rho < 0.878$)]. Self-reflection had a little negative effect on persistence, but it did not reach the significant level on statistics.

5.3 Grade and SRL Behavioural sequence patterns (RQ3)

Table 4 shows that the more effective SRLers had the highest average grade, and others hardly got mark. With one or two SRL phase(s) missing, the average grade dropped. Especially when the self-reflection phase was missing, the grade accelerated dropped slightly. One-way ANOVA analysis and Tukey test showed that the grade of the different types of learners was different significantly ($F = 972.546$, $p\text{-value} < 0.01^{**}$).

Interestingly, there were 15 less effective SRLers who got the full mark (1 point), while only 8 more effective SRLers got the full mark. These less effective SRLers hardly did actions in the forethought phase. Their learning behaviours focused on Course page, video lecture, and quiz. More specifically, they regularly learn in the course with the sequence pattern “C-V-Q”.

Table 4. Grade and More Effective SRLers (MEF-SRLer) and Less Effective SRLers (LEF-SRLer)

<i>Grade</i>	MEF-SRLer (n=1185)	LEF- SRL_mf (n=471)	LEF- SRL_msr (n=1615)	LEF- SRL_mf&sr (n=2034)	Others (n=459)
<i>Mean</i>	0.538	0.410	0.120	0.051	0.002
<i>Std</i>	0.35	0.357	0.238	0.144	0.041
<i>Min</i>	0	0	0	0	0
<i>25%</i>	0.16	0	0	0	0
<i>50%</i>	0.67	0.41	0	0	0
<i>75%</i>	0.85	0.76	0.12	0.01	0
<i>Max</i>	1	1	1	1	0.87

We found that forethought phase had a little negative effect on grade through OLS regression, but it did not reach the significant level. Performance phase had a small positive effect on grade, and it reached the significant level on statistics. Self-reflection had a little negative effect on persistence, and it reached the significant level on statistics [Adj. R^2 (0.544), Prob (F-statistics < 0.001), the coefficients of the three independent values (β -forethought = -0.0009, ρ = 0.639, β -performance = 0.0023, ρ < 0.05*, β -reflection = -0.0013, ρ < 0.05*)].

6 Discussion

6.1 Macro-Level SRL Behavioural Sequence Patterns

Good instructional design is believed to support and stimulate SRL [17]. On the one hand, the course design should be close to the natural SRL process that supports learners' essential capability to self-direct; on the other hand, the more support on the SRL strategies should facilitate different people to construct a personalised learning model for their SRL strategies. Then, if the course was designed with more pages of activities for preparation before performance phase and reflection after performance phase, the learners may pay more attention to the forethought phase and self-reflection phase. In this study, from the course design perspective, this MOOC offers relative concise course design that participants can follow the designed steps to learn one by one easily. Only if the participant persist on the learning activities, they may get a good result. However, those defined less effective SRLers may still have used other strategies that did not leave action records online in these two phases (e.g. time manage on schedule and taking note after learning for reflection).

6.2 Persistence, Grade and SRL

In general, the more effective SRLers were significantly persisting longer and achieving higher than the less effective SRLers. To outward seeming, with the forethought phase and self-reflection phase missing in online learning, both persistence and grade performance dropped dramatically. The decreasing phenomena

especially happened when they missed self-reflection phase. As mentioned above, the self-reflection phase was defined as reviewing progress page after doing the quiz or before reviewing course detail for assessing information again. Before the less effective SRL_msr learners did something on the progress page, they have already made the decision between keep learning in this course and other potential events. In other words, when we see a learner missing the reflection phase in this course, he/she may have already logged out of the course at that time. That is why the decreasing of persistence and grade was steeper than those just miss the forethought phase.

Regarding the multiple regression results, how much the learners did in each phase had little or no effect on both persistence and grade. For the full mark less effective SRLers, these learners may have a clear purpose in this course, such as getting a certificate (performance goal), because their learning sequence pattern was regularly on “C-V-Q...C-V-Q”. And their understanding of these contents was well. However, we did not know if they have reviewed the videos or checked other learning resources before taking the quiz (micro-level). Therefore, exploring the micro-level behaviours is necessary to explain the learning performance in future studies.

7 Conclusion

More effective SRLers and less effective SRLers were differentiated based on the three SRL phases behavioural sequence patterns according to Zimmerman’s three stages of SRL. The finding showed that more effective SRLers outperform less effective SRLers on both persistence and grade significantly. Compared to the Zimmerman’s SRL model, the concrete SRL behavioural sequence patterns were constructed through n-gram method. However, the definition of the SRL behaviours in this study was on narrow sense, which means more patterns can be involved in other situations. In future studies, micro-level behavioural sequence patterns studies can be explored.

8 Limitations and Future Studies

In online learning setting, participants’ learning process is the result of both internal and external factors, including people’s motivation, emotion, psychological and cognitive thinking, and online learning environment. In this study, we only focused on the macro-level behavioural sequences from the superficial perspective based on a fixed online learning environment design. According to Zimmerman’s three stages model [15], SRL is a cycle. It is difficult to separate SRL from subsequent three stages activities. Furthermore, n-gram algorithm helps us capture the most frequent behavioural sequences from the long clickstream based on the pre-defined patterns. However, it will not automatically help us identify different types of behaviours. In future, two aspects can be explored: 1) supplemented internal factors research to validate the impact of SRL behavioural sequences on achievement; 2) design-based MOOC experiment to see what kind of course design or interface navigational design can facilitate more effective SRL behavioural sequences that lead to higher achievement, persistence and engagement.

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