Digital Literacy and Self-Regulated Learning: Testing Reciprocal Relationships with Longitudinal Data

Completed Research

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Abstract

Personal learning environments (PLEs) are disrupting contemporary education, offering opportunities for enhanced use of technology for learning. To maximize these opportunities it is imperative to understand how learners’ technological fluency and self-regulated learning skills are interrelated within PLEs. This paper presents the quantitative findings of an ongoing longitudinal mixed methods study to identify and describe these relationships between digital literacy and self-regulated learning skills. Structural equation modeling is used to test competing models using online survey data from 181 participants in a two-wave panel design. The results support the acceptance of a non-recursive model with significant positive reciprocal relationships between digital literacy component constructs and the self-regulated learning construct. We contribute via empirical evidence, to clarifying the direction and extent to which digital literacy and self-regulated learning skills of undergraduates influence each other. The paper concludes with a discussion of implications for theory and practice together with future research opportunities.

Keywords

Personal learning environments, digital literacy, self-regulated learning, non-recursive model.

Introduction

Personal learning environments (PLEs) are defined as informal learning environments comprising of all the different digital tools and technologies learners use in their everyday life to take control of and manage their own learning (Attwell 2007). Components and content of these student centered and created PLEs are adopted and adapted to fit individual learning needs, rarely limiting to a single technology, device, application or activity (Hricko 2017).

Self-regulated learning (SRL) within a social-cognitive perspective is defined as the deliberately generated thoughts, feelings, and actions that are repetitively adapted for attaining personal learning goals. It is a cyclic interaction of the person (self), the behavior (action) and the environment within three successive phases of (1) forecasting (processes preceding the learning effort), (2) execution control (processes occurring during learning) and (3) self-reflection (processes that occur after learning) (Zimmerman 2000). PLEs support regulation of self, behavior, and environment via collecting, planning, monitoring and adapting independent learning tools and resources to realize an explicit learning goal. Thus, PLEs enable learners to remain attentive, motivated, and engaged in learning tasks, making SRL an essential characteristic of the PLE (Melzer and Schoop 2015).

PLEs are also regarded as a context for developing digital literacy (DL) skills (Laakkonen and Taalas 2015). DL is the collection of literacies associated with the usage of digital technologies including desktops, mobile devices (e.g. laptops, tablets, smartphones, PDAs), Web 2.0 tools and other collaborative resources on the internet as well as any open source or commercially available software packages, for learning. The associated multiple literacies consist of: photo-visual literacy; reproduction literacy; branching literacy; information literacy; socio-emotional literacy and real-time thinking skill (Eshet
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These are incorporated into three components of DL (Ng 2012), consisting of (1) technical literacy (TL) defined as technical and operational skills needed to competently use digital technology, (2) cognitive literacy (CL) defined as cognitive skills used in information search, retrieval skills using technology and knowledge on related ethical, moral and legal issues, and (3) social-emotional literacy (SEL) defined as the literacy associated with the emotional and social aspects of online socializing, collaborating, evaluating information, and using digital technology for collaborative knowledge construction.

DL is an area which has been criticized for its lack of comprehensive integrative frameworks and theoretical foundation, as the discourse in this area is mainly practice-oriented. While researchers imply that DL could have a much deeper link to the learning strategies and particularly SRL skills of students, empirical evidence is lacking (Prior et al. 2016). Moreover, most prior studies in the area are cross-sectional and employ an experimental approach imposing particular technologies on the research participants, and do not investigate how the current PLE used in daily life and DL and SRL skills gained herein could be interrelated. Although there is some general agreement that these relationships exist, the nature, magnitude and the causal direction of the relationships between DL and SRL within PLEs is not yet clarified. Thus, prior studies are unable to provide sound empirical evidence of how DL and SRL skill interaction takes place within user controlled and managed informal PLEs, even though the creation of such PLEs is a prevalent learning strategy among contemporary learners.

The objective of this study is to use longitudinal data to explore the direction and causal nature of the relationships between DL and SRL skills of a representative sample of undergraduates, within the context of their technology-based informal PLEs. Findings of this study are expected to augment the ongoing discussion among Information Systems (IS) researchers on understanding technology use and the role of technology in teaching and learning by providing insight on the causes and effects of DL skills developed and fostered through the informal use of technology via PLEs. The results would also deepen our understanding of how academic self-regulatory behaviors could vary as a result of interaction with technology for learning and digital skills developed herein, creating a more precise picture of the interrelationships between DL and SRL constructs within PLEs.

A discussion of related work, research method employed in this study and the results of the investigation follows. The paper concludes with its contributions and directions for future research.

Background and Hypotheses

Prior research affirms that the use of technology and skills gained herein can foster self-regulated learning (SRL) in higher education contexts (Dabbagh and Kitsantas 2012). Recent studies have evidenced that diverse technological tools supported different SRL processes (Yot-Domínguez and Marcelo 2017). Other studies (e.g. Goh et al. 2012; Kauffman et al. 2011) indicate that the use of technology impacts how SRL skills are developed and nurtured. Much of this existing research focuses on investigating the SRL processes and actions of students with relation to technology and narrowly consider the capabilities of technology in itself. However, technical, cognitive and social emotional skills of technology users are a prerequisite and logical determinant for effectively using technology for learning (Tang and Chaw 2016). The literacy framework proposed by Beetham et al. (2009) theorized that a highly digitally literate student could be better at regulating their learning activities via the use of technology than a less digitally literate counterpart. While recent research conducted within a university e-learning environment posit a strong positive correlation between digital literacy (DL) and SRL skills of learners (Yang and Kim 2014), research investigating DL as an antecedent for how well learners regulate their learning is still lacking. Further, holistically considering the previous research it can be argued that DL acts as a determinant of how well learners are able to regulate their learning in technology enhanced learning environment such as personal learning environments (PLEs). Thus, we hypothesize that DL at Time 1 positively influences the SRL skills of students at Time 2. (H1)

Additionally, research indicates that DL requires effective SRL. SRL processes enacted while learning with computer-based digital tools have been comprehensively documented (Greene et al. 2014). Aspects of self-regulation in learning are also thought to be component skills in some digital literacy definitions, indicating that in order to develop DL skills; SRL skills are antecedent. Successful intervention studies detail the promotion of DL as part of a larger focus on students' SRL (Jung and McMahon 2012). In view
of this prior research, and the cyclic nature of SRL, self-regulated learners could plan and monitor learning actions performed on and via the PLEs and upon reflection take appropriate behavioral action for applying and furthering DL skills to enhance the learning experience within the PLEs. The SRL capabilities of the student, therefore, could have a positive influence on how well he/she applies DL skills for the learning task. As proposed by Valentín et al., (2013) this relation between SRL strategies and digital skills may even be casual. Consequently, we hypothesize that SRL at Time 1 positively influences DL of students at Time 2 (H2).

Finally, there is reason to believe that the relationship between SRL and DL is reciprocal, as suggested by some authors (e.g. Besbes, 2016; Steiner et al., 2013). Analysis of individual DL components and SRL components of undergraduates using cross-sectional data has provided some evidence of the existence of reciprocal influence (Perera Muthupoltotage and Gardner, 2018). This reciprocal relationship is best understood via the consideration of a commonly occurring learning scenario among contemporary learners. Consider an undergraduate using online search tools (e.g. a web-based search engine) of their PLE for accessing further information related to a particular subject, previously discussed in class. In order to maximize learning, he/she should be able to effectively plan the search task to increase usefulness and relevance of information, data, videos or interactive simulations obtained via the Internet. The learner would possess some ability to monitor and evaluate the impact of these resources on his/her knowledge. Reflecting on how the information received augments current knowledge, and organizing subsequent learning activities accordingly should also be done. At each stage, the learner may well utilize various components of their PLE (e.g. planning and scheduling tools, resource management tools, word processing tools). The learner may even discuss the information obtained with peers via social networks and communication tools integrated into the PLE, seeking their assistance for enhanced understanding. These activities of (i) planning, (ii) cognition, (iii) monitoring and, (iv) regulating are component skills of SRL (Zimmerman, 2000). Moreover, in terms of DL skills necessary for completing the learning task successfully, the learner needs to competently use the web-based search tools and other communication tools (i.e. technical literacy). He/she should critically evaluate and select the information required while being knowledgeable of related ethical, moral and legal issues related to web-based activities such as plagiarism (i.e. cognitive literacy). Observing ‘netiquette’ while avoiding misinterpretation and misunderstanding and showing an awareness of privacy and individual safety concerns (i.e. social-emotional literacy) is also relevant here.

Without successfully applying both DL and SRL skills the learner would not be able to complete the learning task effectively via his/her PLE. However, at a conceptual level, it can be argued that learners’ level of DL in terms of ability to select and effectively, yet, ethically use technology, would consequently influence how well the learner is able to engage in SRL activities. Moreover, how skilled the learner is in regulating his/her own learning could subsequently influence how well the learner is able to demonstrate technical, cognitive and social-emotional literacy when engaging with technology within the PLE. Therefore we finally hypothesize that DL and SRL mutually influence each other (H3).

Our study examined these hypotheses using several cross-lagged panel models of the relationship between DL constructs and SRL skills, controlling for the effects of age and gender. The purpose of this paper is to compare the relative fit of these competing models and select the best fitting model. Such an analysis would help clarify the nature and magnitude of the relationships among these constructs and their pattern of change over time complementing our understanding of digital disruption caused by educational technology use.

Methodology

Participants and Procedures

The participants consisted of a random sample of 181 first-year undergraduate students enrolled in courses within the Business faculty of a top university in the Asia-Pacific region. Data collection was performed using online surveys via Qualtrics. In the first phase of data collection, the survey was emailed to participants in July 2016 and the respondents asked to indicate willingness to participate in the second follow up survey. Respondents who agreed to continued participation in the research were emailed the survey again for the second phase of data collection in March 2017. Due to lack of prior research in this area, yet, there is no clear basis for specifying the appropriate time lag between variables. The interval we
used between the two measurement points was 8 months. This accounted for capturing data points across two academic years for the participants. The gender distribution revealed more females than males (59% vs. 41%). The sample’s age ranged from 16-30 years with a mean age of 19 years (SD = 2.007), while 79.8% were between 18-20 years old.

**Materials**

Both measurement scales for digital literacy (DL) and self-regulated learning (SRL) were 5 point Likert scales ranging from 1 ‘strongly disagree’ to 5 ‘strongly agree’. Measurement scales for DL were drawn from the instrument used by Ng (2012) consisting of 1) technical literacy (TL) (6 items), 2) cognitive literacy (CL) (2 items), 3) social-emotional literacy (SEL) (2 items). In this study, the scale demonstrated internal consistency reliabilities of α = .956 at time 1 and α = .867 at time 2, and a test-retest reliability of .902 (p<=0.001).

The seven-factor structure from the academic SRL scale (Magno 2010) was used for measuring self-regulated learning. It consisted of (1) Memory strategy (14 items), pertaining to strategies used for memorizing and retaining information. (2) Goal-setting (5 items), involving setting specific proximal goals for oneself. (3) Self-evaluation (12 items), is the constant reflection on and rectification of one’s learning methods for achieving learning goals. (4) Seeking assistance (8 items), is actively obtaining help from outside resources to supplement learning including teachers or peers as well as digital resources. (5) Environmental structuring (5 items), is restructuring one’s physical and social context for compatibility with one’s learning goals. (6) Learning responsibility (5 items), is ascribing causation to results, and adapting future methods. (7) Organizing (6 items), involves monitoring performance selectively for signs of progress while efficiently managing time. In this study, the scale demonstrated internal consistency reliabilities of α = .988 at time 1 and α = .924 at time 2, and a test-retest reliability of .972 (p<=0.001).

**Statistical Analysis**

Structured equation modeling (SEM) technique, was used for statistical analysis. SEM enables characterization of real-world processes better than simple correlation-based models. Using SEM to compare models enabled the examination of autoregressive effects that describe the stability of DL and SRL across different time points, while simultaneously examining hypothesized effects of one construct on another across time. Therefore, while being consistent with the recommendations of Farrell (1994) for evaluating reciprocal relations, bias in estimating hypothesized cross-lagged effects are also minimized.

**Strategy for Model Testing**

Due to the large number of items used to operationalize the higher order SRL construct, as a first step in the analysis, the reliability and validity of the primary order factor structure of the academic SRL scale was examined for each wave of data collected using confirmatory factor analysis (CFA) with AMOS Graphics 24.0. The indicator loading of each indicator on its relevant SRL construct together with model fit indices for each wave were examined. For both waves of data, acceptable model fit was achieved for the first-order structural models at each wave, (Time 1 relative chi-square (CMIN/DF) = 2.101, comparative fit index (CFI) = 0.907, Goodness of fit index (GFI) = 0.91; Time 2 CMIN/DF =2.429, CFI= 0.943, GFI = 0.903). Next, imputed factor scores from the first order factor models were used for including the SRL second-order latent construct in the construction of a measurement model for all latent constructs. The measurement model consisted of three latent constructs for DL and seven second-order latent constructs for SRL at each wave. The measurement model validity and reliability was investigated and established (see Table 1).

Next, imputed factor scores for SRL, TL CL and SEL were used for specifying four competing structural panel models, by including each construct as a latent variable. This approach is recommended for its ability to minimize problems of unreliable parameter estimates and insufficient power (de Jonge et al. 2001). Age and gender (coded 1 for Males and 2 for Females) were integrated as control variables in the models, assumed to be directly related to Time 1 variables and only indirectly at Time 2.

In the first stability model (Model 1 in Figure 1 below), we suggest that DL and SRL do not influence each other directly but share variance caused by unmeasured factors, therefore only the auto-regressive effects
of each variable across the two waves are specified. Then, this stability model was compared with the three other models in Figure 1. The second model (Model 2 in Figure 1), specified cross-lagged structural paths from Time 1 TL, CL, and SEL to Time 2 SRL, reflecting hypothesis H1. The third structural model (Model 3 in Figure 1), is a reversed causal model specifying cross-lagged structural paths from Time 1 SRL to Time 2 TL, CL, and SEL, reflecting hypothesis H2. The fourth is a nested model of the previous two, (Model 4 in Figure 1) and indicates reciprocal relationships between the DL component construct and SRL construct reflecting hypothesis H3.

![Correlations Table](image)

Table 1. Validity and Reliability of Constructs

Model Comparison and Estimation

Chi-square difference test (X²) was used to compare the different nested structural models in separate analysis steps. An overview of model comparison is summarized in Table 2. The first test indicated a
significant (p< 0.001) difference between the stability model (Model 1) and the model with cross-lagged effects from digital literacy (DL) to self-regulated learning (SRL). Therefore it was determined that the unconstrained model (Model 2) better accounts for the data than the constrained model with no lagged effects. Thus there is statistical evidence that Time 1 DL constructs significantly influence SRL at Time 2.

<table>
<thead>
<tr>
<th>Model</th>
<th>X²</th>
<th>df</th>
<th>Comparison</th>
<th>ΔX²</th>
<th>Δdf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>143.427***</td>
<td>53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 2 (DLT1 -&gt; SRLT2)</td>
<td>137.098***</td>
<td>50</td>
<td>Model1 vs Model2</td>
<td>6.329 p = 0.097</td>
<td>3</td>
</tr>
<tr>
<td>Model 3 (SRLT1) -&gt; DLT2</td>
<td>135.917***</td>
<td>50</td>
<td>Model1 vs Model3</td>
<td>7.51 p = 0.057</td>
<td>3</td>
</tr>
<tr>
<td>Model 4 (reciprocal)</td>
<td>121.588***</td>
<td>47</td>
<td>Model1 vs Model 4</td>
<td>21.839 p = 0.001</td>
<td>6</td>
</tr>
<tr>
<td>Model 2 vs Model 4</td>
<td>15.51 p = 0.001</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model 3 vs Model 4</td>
<td>14.329 p = 0.002</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Structural Model Comparison

The second chi-squared difference test indicated that the unconstrained Model 3 also better accounts for the data than Model 1. Therefore statistically SRL at Time 1 can influence DL components at Time 2. When the stability model was compared with the reciprocal model with all cross-lagged structural paths (Model 1 vs Model 4), the test showed a significant improvement in model fit. Similarly, as seen in Table 2, Model 4 appeared to fit the data better than Model 2 and 3, in terms of chi-square relative to the degrees of freedom at a 99% confidence interval. The important fit indices for Model 4 (GFI = 0.901 CFI = 0.967, normed fit index (NFI) = 0.837, root mean square error of approximation (RMSEA) = .07) revealed a relatively better fit according to criteria presented by Hu and Bentler (1999).

Note: * p<0.1 ** p < 0.05, *** p < 0.001. Dashed lines are insignificant relationships.

Figure 2. The Final Longitudinal Structural Model (Model 4)

The expected cross validation index (ECVI) was also compared for the 4 models to determine robustness of Model 4. As the sample of 181 subjects in the current study is not conductive for cross-validation, the single sample cross validation method was adopted (Browne and Cudeck 1989). The 1.253 ECVI for Model 4 was lower than the ECVI values for Model 2 (1.611) and Model 3 (1.771). Thus, indicating a good fit for the data. Therefore reciprocal Model 4 better accounted for the data and is the more stable model. Rogosa (1979) recommends that once the existence of reciprocity is determined, the specific causal effects.
and the measures of strength of individual relationships should be examined. The standardized estimates for the structural paths of Model 4 are shown in Figure 2 above.

It appears that SRL at Time 1 significantly influences DL components at Time 2. Further, higher levels of TL, CL and SEL causes higher levels of SRL at Time 2. Thus the data supported the hypothesis that the DL and SRL constructs mutually influence each other (hypothesis H3).

Discussion

We used a two-wave panel design and empirical analysis applying SEM technique to examine the direction and extent to which self-regulated learning (SRL) and digital literacy (DL) constructs influence each other. The results support hypothesis H3 confirming that after controlling for age and gender DL and SRL constructs are reciprocally related.

Closely inspecting our results it is seen that SRL has a statistically significant positive effect on all components of DL. The largest effect is on social-emotional literacy (SEL). SEL, in general, is a multidimensional construct that includes the ability to understand, recognize, and label one's own and others’ emotions; appropriately express, control, and regulate one's own feelings and behaviors; effectively establish, maintain, and manage social relationships; and make responsible choices and decisions (Nikolayev et al. 2016). SEL in relation to technology requires users to be highly critical and analytical, very mature, and have a good knowledge of socially acceptable behavior regarding collaborative technology use. This has been described as the highest-level and most complex of the digital literacy skills (Eshet 2012). The personal learning environment (PLE), while individual in nature, provides opportunities for creating shared learning spaces (Liew & Kang, 2012). Collaboration with peers for learning tasks is an essential factor for SRL within PLEs, particularly for seeking assistance and environment structuring (Nussbaumer et al. 2015). Therefore how well a learner engages in these collaborative regulatory tasks within a PLE and skills gained herein, could well influence their subsequent abilities to demonstrate critical thinking, maturity and acceptable behavior when engaging with others using technology. SEL also influences the SRL level of our subjects at Time 2. Demonstrating responsible and acceptable behavior when connecting with others over the social tools, such as social networks of one’s PLE is important to ensure ready and effective collaboration with peers (Conole 2013). The social-emotional skills honed in this manner, would then be put to use when engaging in collaborative SRL behaviors. The implications are also considerable in light of the concern that some authors express about lack of opportunities for contemporary learners to develop their social and emotional skills while relying on technology as their primary source of social interaction (Liew et al., 2010).

Technical literacy (TL), which involves possessing the applicable technical and operational skills to employ digital technologies for learning within PLEs, has a positive influence on SRL. A possible reason might be the prolific use of organizers and schedulers accessible on mobile phones and other devices integrated on to typical PLE for planning and management of their activities. Further, communication tools partnered with file sharing mechanisms enables fast feedback on tasks together with seamless collaboration. Web-based formal and informal social network environments partnered with forums and blogs enable the restructuring of students’ social environment to suit their goals. These are common components of PLEs. Thus, the technical ability to use these tools efficiently for learning will influence how well the SRL related activities such as planning and environment structuring will be executed. TL contributes to the overall success of the learning environment and our findings draw a parallel with prior studies which suggest that successful online learning environments may enhance learners’ self-regulation (Vighnarajah et al. 2009) The relationship between SRL and TL is reciprocal.

There are several reasons why such a relationship may exist. The construction of a PLE involves the awareness of, experimentation with and selection of various tools which the learner feels will aid in their learning processes (Castañeda and Soto 2010). This involves the management of tools within the PLE, setting technology aided learning goals, initiating control and regularly monitoring, evaluating and structuring of the PLE environment. (Valtonen et al. 2012). These are SRL behaviors which have been shown to influence the level of initiative regarding PLE construction, where the level of initiative involves the ability to evaluate different tools for their technical capabilities and use them effectively (Yen et al. 2005).
In a prior study conducted using a case study approach, Willem, Aiello, & Bartolome, (2006) investigated if critical thinking towards the media was promoted through the acquisition of SRL skills in a technology-enhanced learning environment (TELE). They investigated various aspects of information literacy (i.e. analyze and evaluate information, judge the reliability). It was seen that students used some SRL strategies influencing their information literacy. Given that information literacy is an aspect of cognitive literacy (CL) our findings that SRL significantly influences CL is in agreement here. Application of cognitive strategies such as rehearsal, elaboration, and organization are an important aspect of being a self-regulated learner. They help students pay attention to the lesson, select important information and retain that information in memory (Sadi and Uyar 2013). The consistent use of such strategies using the tools of a PLE could possibly be fostering the information literacy and critical thinking skills which form the cognitive literacy component of DL. Our results indicate that this relationship between CL and SRL is also reciprocal. Searching, evaluation and organization skills honed via the use of common PLE tools such as search engines and personal organizers, could be directly translated to strategies for evaluating information when learning both in and outside the classroom and organizing oneself as well as ones learning activities. The transferability of these cognitive skills could be the reason for the reciprocal relationships our results indicate.

Contribution and Outlook

Our theoretical contribution is twofold. First, our findings provide an opening for a comprehensive dialogue among researchers who are interested in understanding the patterns, contexts and consequences of technology adoption for learning in informal PLEs. As very few longitudinal studies have been conducted to examine DL and SRL within PLEs our findings add to the literature in this area. Next, the explicit comparison we did of competing models carries more conviction than testing and failing to reject just one model. The measurement model could confirm that the DL and SRL constructs we used have appropriate reliability and validity and could encourage other researchers in incorporating these constructs in their research.

Practically, our findings indicate that learners are developing DL and SRL skills within the PLE frameworks that they create, in line with the constructivist learning environment paradigm where learners are said to make meaning of their own experiences (Jonassen and Land 2012). Teachers, institutions and other stakeholders should be sensitive to the possibility and the potential affordances that this creates for enhancing the learning experience and supporting skill acquisition and enhancement. This is particularly important when considering the proven influence that SRL has on academic achievement (Said 2013).

PLEs are often criticized for their difficulty to be applied in educational settings as users may not have the technological fluency and self-regulatory skills necessary to create an effective PLE (Tu et al. 2015). Our findings can be used to develop evidence-based scaffolding programs for effective PLE creation as the reciprocity of DL and SRL suggest that the learners are teaching themselves the required skills. Further, this also indicate opportunities for information systems educators who are keen to match technology with pedagogy, without allowing technology to drive teaching methods. The reciprocal causality of DL and SRL within the informal technology use context indicates that it would be quite seamless to integrate these same technologies that students commonly use within, and to facilitate formal courses while controlling the cognitive load on both the learners and the teachers.

Next, this exploratory analysis paves the way for further research. A qualitative analysis incorporating the examination of mind maps of actual PLEs constructed by students, combined with face to face semi structured interviews could help in explaining and clarifying the above findings as well as identifying further factors which could influence this phenomena. The qualitative analysis is presently underway and findings will be forthcoming.

REFERENCES


