The Moderating Effects of Gender and Need Satisfaction on Self-Regulated Learning Through Artificial Intelligence (AI)

Citation:

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Abstract: Artificial intelligence (AI) has the potential to support self-regulated learning (SRL) because of its strong anthropomorphic characteristics. However, most studies of AI in education have focused on cognitive outcomes in higher education, and little research has examined how psychological needs affect SRL with AI in the K–12 setting. SRL is a self-directed process driven by psychological factors that can be explained by the three basic needs of self-determination theory (SDT), i.e., autonomy, competence, and relatedness. This study fills a research gap by examining the moderating effects of need satisfaction and gender in predicting SRL among Grade 9 students. The results indicate that girls perceive stronger needs support for autonomy, competence, and relatedness than boys. In predicting SRL, satisfaction of the need for autonomy and competence is moderated by both gender and AI knowledge, whereas satisfaction of the need for relatedness is moderated by gender only. Particularly among girls, the effects of autonomy and competence more strongly predict SRL when AI knowledge is low. These findings confirm the gender differences in need satisfaction when predicting SRL with a chatbot. The findings have implications for both teacher instruction and the design and development of intelligent learning environments. To better understand the effects, more longitudinal studies are suggested for future studies.

Keywords: Self-Regulated Learning; Self-Determination Theory; Artificial Intelligence; K–12 Education; AI Knowledge, Chatbot

Introduction

The development of artificial intelligence (AI) technology is creating new opportunities and challenges for teachers. However, how to effectively use the emerging technology to foster learning remains unclear (Chew & Chua, 2020; Palasundram et al., 2019), particularly in K–12 education. AI technology has strong anthropomorphic characteristics and the ability to interact with students (Blut et al., 2021; Pelau et al., 2021), which could provide a better digital environment for self-regulated learning (SRL). SRL refers to activities "students do for themselves in a proactive way rather than as a covert event that happens to them in reaction to teaching" (Zimmerman, 2006, p. 705– 722). SRL is strongly associated with students' psychological needs when learning with digital technologies. For example, SRL is associated with online learning and needs satisfaction (Luo et al., 2021; Zhou et al., 2021). Compared with non-AI technologies, AI has been found to provide more personalised learning environments (Blut et al., 2021; Pelau et al., 2021). For example, intelligent tutoring systems provide supports through feedback and recommendation. With these affordances, students may choose to build their competencies according to their own pace without waiting for teacher assistance. Nonetheless, students would need to have knowledge about the characteristics of the AI system to employ the system effectively in support of their learning. Thus, more investigation is needed into the use of AI technology to support students' SRL (Hussin, 2018).

Students' psychological needs can be explained by self-determination theory (SDT). SDT is particularly concerned with how social-contextual factors support or thwart people through the satisfaction of their basic psychological needs for competence, relatedness, and autonomy (Ryan & Deci, 2017). These needs are linked to motivational processes that promote and encourage student SRL (Grolnick & Raftery-Helmer, 2015; Liu et al., 2014). When the psychological needs

are satisfied, the students become more autonomously motivated, thereby assuming agency to self-regulate their learning (Liu et al., 2014; Sierens et al., 2009). From the perspective of SDT, SRL can be understood as the outcome of motivational processes; thus, teachers should support students' needs for competence, relatedness, and autonomy to engage students in SRL. Accordingly, SDT can provide teachers with a theoretical basis to support students' SRL with AI.

SDT-related research on learning technology has mostly focused on higher education, and studies of AI in education have concentrated on cognitive outcomes and adaptive learning (Chiu, 2022; Chiu et al., 2021; Alowayr & Al-Azawei, 2021; Huang et al., 2019; Jeno et al., 2019). Accordingly, there has been little related research on how need satisfaction affects SRL in AI-supported environments in the K–12 setting (Chiu, 2021; Chiu et al., 2022; Hsu et al., 2019; Xia et al., 2022). Moreover, gender differences have been reported for each of the SDT-based needs (Lietaert et al., 2015). For example, boys have been found to prefer more support for autonomy compared with girls. This study aims to fill the research gaps by examining the effects of need satisfaction and gender when predicting SRL in Grade 9 students. The findings should clarify the differential SDT need effects of SRL and gender. The three research questions are:

RQ1. What is the relationship between AI knowledge and SRL with AI? (Please refer to H1)

RQ2. Do female students perceive higher needs satisfaction for autonomy, competence and relatedness than male students when SRL with AI? (Please refer to H2)

RQ3. How does gender interact with need satisfaction and AI knowledge when predicting SRL? (Please refer to H3)

To answer these questions, this study proposes and examines the research model shown in Figure 1. The following section discusses the significance of this study and how the literature supports this proposed model.

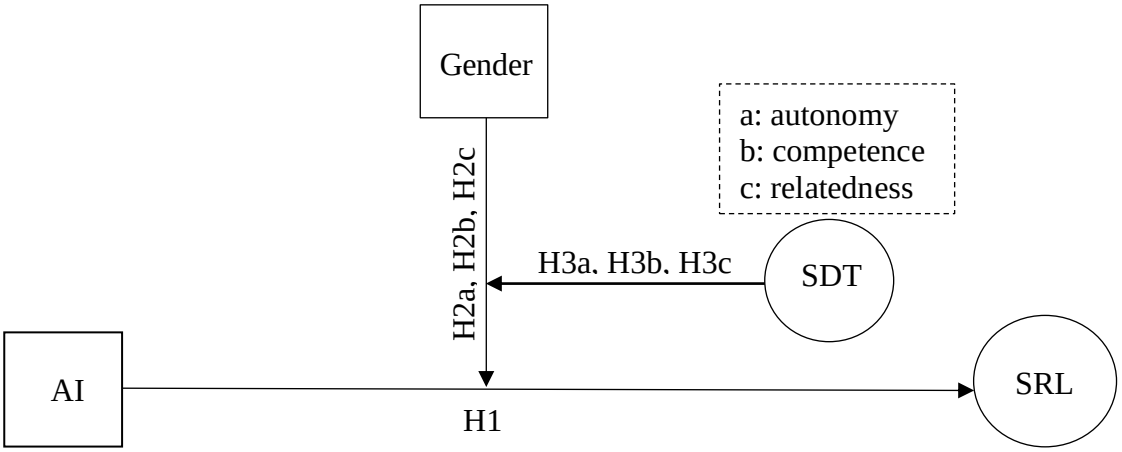

Figure 1. Research model.

Theoretical Framework

How AI Knowledge Influences SRL and Gaps in the Research

According to Zimmerman's model (2006), SRL involves a three-phase learning cycle of forethought, performance, and self-reflection (Zimmerman, 2006). The learning process in each of these phases is influenced by the students' characteristics, such as interest, self-efficacy, and

experience (Panadero et al., 2017; Virtanen & Nevgi, 2010; Yukselturk & Bulut, 2009). Figure 2 below depicts the general phases of SRL activities.

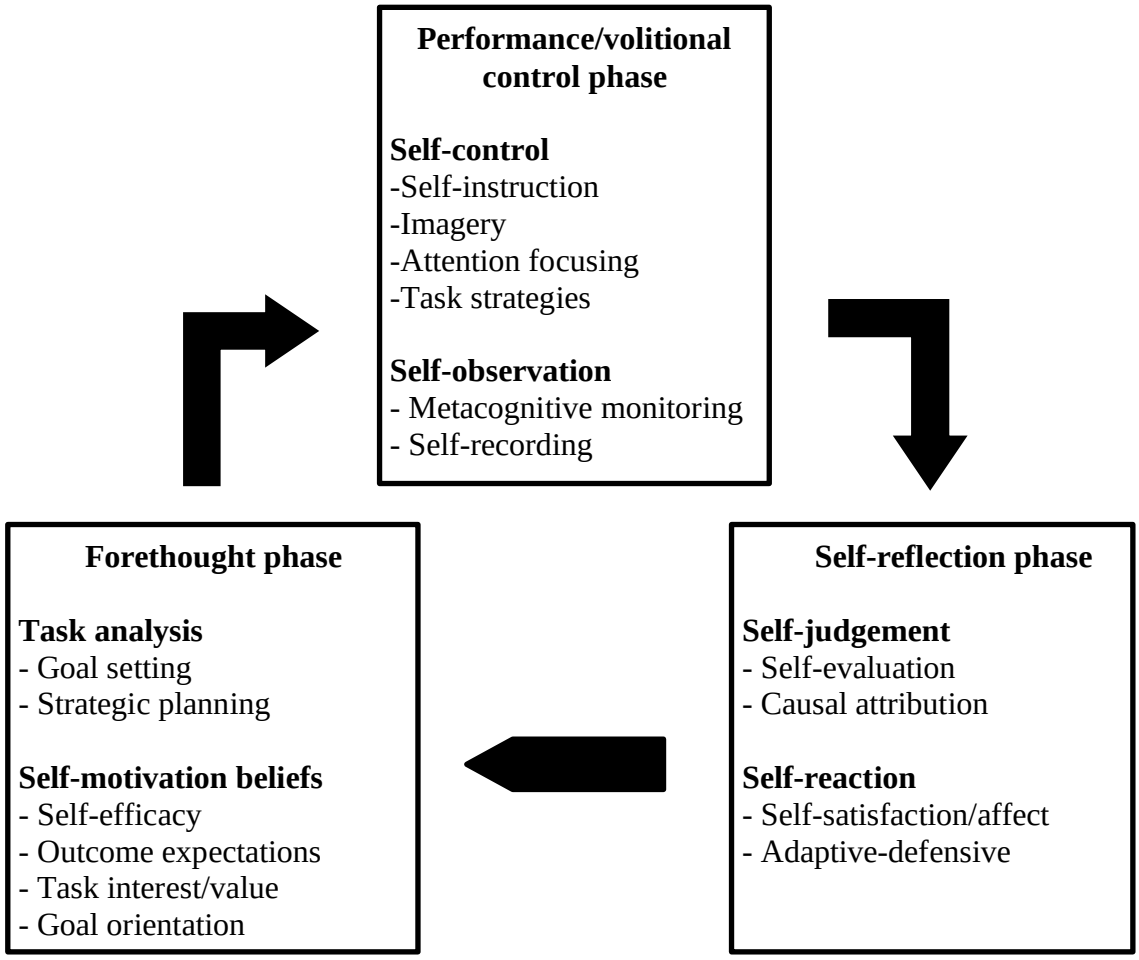

Figure 2. Phases of SRL (Zimmerman, 2006)

AI knowledge refers to the ability to comprehend the core concepts of AI, which is affected by the students' AI experience (Kim et al., 2021). Therefore, students' AI knowledge influences their SRL with AI applications.

In the first phase of Zimmerman's SRL model, students need to plan their learning goals and tasks with tools based on their own interests and self-efficacy, which their prior AI knowledge may influence. The second phase concerns implementing their learning plan, and involves help-

seeking, task strategies, and environmental structuring. When seeking help, students with a good knowledge of AI are more likely to ask the right questions to solve their problems in AI-based learning environments, whereas those with weak AI knowledge have difficulty asking the right questions. The third phase concerns preparing for the first phase of the new cycle and requires students to reflect on what they have learned from their tasks and how they used their learning tools. This reflection process is directly influenced by their learning experience in the first two phases. Prior AI knowledge involved in the first two phases should indirectly influence the learning process in this phase and therefore have positive effects on SRL with AI. This assumption is supported by technology acceptance models such as TAM (Davis, 1989). In this model, computer self-efficacy is one of the factors affecting perceived usefulness, perceived ease of use, attitudes toward using, and behavioural intention to learn with technology (Chiu, 2017; Ong & Lai, 2006; Roca et al., 2006). How students perceive their computer self-efficacy determines whether they think the technology is valuable and user-friendly. This implies that student AI knowledge affects their SRL with AI. Hence, in this study, it is hypothesised that students with higher AI knowledge will score higher in SRL (H1).

Another factor affecting technology acceptance is gender (Cai et al., 2017; Ong & Lai, 2006). Studies have reported two major gender differences in technology acceptance. First, female students have been shown to be more strongly influenced by the perception of computer self-efficacy, ease of use, and playfulness, whereas male students have been more influenced by perceived usefulness (Bao et al., 2013; Ong & Lai, 2006; Padilla-Meléndez et al., 2013; Venkatesh & Morris, 2000). Second, studies have found that female students are more likely to experience anxiety and tend to be less interested in using technology for learning (Colley & Comber, 2003; Schottenbauer et al., 2004; Venkatesh & Morris, 2000; Wang & Wang, 2008). Accordingly, gender

is an important moderator of technology acceptance (Venkatesh et al., 2003; Venkatesh et al., 2012).

As we discussed, most studies of gender differences in technology acceptance have not taken into account the satisfaction of students' need for competence, autonomy and relatedness. However, SRL requires iterative learning cycles and long-term effort and investment from students. Therefore, current research may not fully explain how gender differences affect SRL with AI. Need satisfaction in SDT influences the fulfilment of meaning-making, well-being, and finding value within internal growth and motivation (Ryan & Deci, 2017, 2020). To fill this gap, this study uses need satisfaction to explain the relationships between AI knowledge and SRL and can thus enrich our understanding of the use of SRL with AI.

Autonomy and Effects of Gender on SRL

Autonomy is defined as freedom or the perceived ability to choose one's actions (Chiu, 2017, 2022; Ryan & Deci, 2017). Students who feel greater autonomy demonstrate more enthusiasm, focus, and purpose in their learning and exemplify how self-regulated learning takes place (Deci & Ryan, 2002; Grolnick & Raftery-Helmer, 2015). Studies have found that students' capacity to regulate their own learning is positively affected by satisfying their need for autonomy (Holzer et al., 2021; León et al., 2015; Radel et al., 2014). Previous studies (Flowerday & Schraw, 2000; Kim et al., 2022; Schraw et al., 2001) found autonomy support is beneficial for students with low SRL skills, as providing choice opportunities or adding relevance to the task can predict their lower temptation, higher positive affect, and lower negative affect. Autonomy support is the instructional effort that teachers provide during instruction (Chiu, 2022; Xia et al., 2022), including the affordance of choice and encouragement of self-regulation (Ryan & Deci, 2017). The principal ways to support students' autonomy are to provide them with meaningful choices and to use non-threatening body

language (Assor et al., 2002; Black & Deci, 2000; Katz & Assor, 2007; Niemiec & Ryan, 2009; Patall et al., 2010; Young-Jones et al., 2014).

Gender differences may lead to varying degrees of perceived autonomy support. Studies have found that female students perceive more autonomy support from their teachers than male students do (Cheon et al., 2012; Kındap-Tepe & Aktaş, 2021; Lam et al., 2012; Lietaert et al., 2015; Mandigo et al., 2008; Vantieghem & Van Houtte, 2015). For example, a study of Dutch language classes found that boys reported lower engagement and less support from their teachers than girls did. However, autonomy support was shown to increase engagement among male but not female students (Lietaert et al., 2015). Another study of a game lesson for students in Grades 4 to 7 found that girls perceived higher levels of autonomy support, whereas boys perceived higher levels of competence support (Mandigo et al., 2008). Zhou (2016) found that student autonomy had both direct and indirect effects on their language learning abilities, with female students having a higher level of SRL than male students. Overall, the research has shown a trend of female students receiving more autonomy support and thus being more engaged in SRL than male students.

Given these past findings on gender differences in autonomy support and SRL with AI, in this study, it is hypothesised that female students will score higher than male students on measures of autonomy support (H2a) and that gender will moderate autonomy support when predicting the relationship between AI knowledge and SRL (H3a).

Competence and Effects of Gender and Competence on SRL

Competence refers to the need to master one's pursuits or learning (Chiu, 2022; Ryan & Deci, 2017). Students experience competence when they feel capable of facing the challenges of their schoolwork. Competence is reflected in students' ability to self-regulate their learning (Grolnick

& Raftery-Helmer, 2015). Studies have found that satisfaction of the need for competence can predict students' motivation to self-regulate their learning (Holzer et al., 2021; Mouratidis et al., 2013; Ryan & Deci, 2000). Students' competence can be enhanced through appropriate learning activities (Niemiec & Ryan, 2009). SDT suggests that supporting autonomy and competence is a prerequisite for students' self-determination and intrinsic learning motivation (Niemiec & Ryan, 2009); and that the effectiveness of competence support in the classroom mainly determines these beneficial relationships (Reeve, 2002). Competence support includes the provision of structure and positive informative feedback (Ryan & Deci, 2017), which includes setting clear learning goals, rules, and expectations, offering instant help, guidance, and supervision, and providing positive, constructive feedback (Reeve, 2002; Sierens et al., 2009; Vansteenkiste et al., 2012).

The gender difference in perceived competence support is inconclusive according to previous SDT-based studies. For example, one longitudinal study of Korean secondary school students found no gender differences in students' perceived competence support in the context of unspecified subjects (Jang et al., 2012). However, in another longitudinal study of Korean secondary school students, boys scored higher than girls on perceived autonomy during physical education class (Cheon et al., 2012). A longitudinal study of Canadian high school students found that girls perceived more competence satisfaction than boys in the context of unspecified subjects (Ratelle & Duchesne, 2014). Among cross-sectional SDT-related studies, a study of academic motivation among Hong Kong Chinese secondary school students found that boys perceived higher levels of competence than girls (Hui et al., 2011). However, a study of German adolescents found that competence support had a stronger effect on intrinsic motivation among girls than boys (Schweder & Raufelder, 2021). Overall, the results suggest that girls are likely to show higher levels of SRL than boys, as girls perceive more competence support than boys.

Accordingly, it is hypothesised that female students score higher on competence support measures than male students (H2b) and that gender moderates competence support when predicting the relationship between AI knowledge and SRL (H3b).

Relatedness and Effects of Gender on SRL

Relatedness refers to the sense or feeling of being connected to other people (Chiu, 2022; Ryan & Deci, 2017). Satisfaction of the need for social relatedness was shown to be positively associated with intrinsic motivation and beneficial to self-regulated learning (Liu et al., 2014). For example, students who felt connected to and welcomed by their teachers were more likely to develop identifiable and integrated regulations for their learning tasks than those who felt disconnected from their teachers (Niemiec & Ryan, 2009). Support for relatedness includes the caring involvement of others (Ryan & Deci, 2017), which is related to teacher behaviour that influences their students' relationships with them (Chiu, 2022; Xia et al., 2022). Such behaviour includes the teachers' actions, words, and responses in relation to their students. When teachers are positive, caring, and effective, the classroom climate becomes more fun and interactive (Skinner et al., 2008). Providing opportunities for students to interact can satisfy their need for relatedness and thus positively influence their SRL strategies (Liu et al., 2014).

Gender differences may lead to varying degrees of perceived relatedness support. Studies have suggested that girls are more influenced by relationship factors, such as teachers' expectations and support (Goodenow, 1993; McCormick & O'Connor, 2015; Ryan et al., 1994). Bru et al. (2021) found that the association between the structuring of learning activities and engagement was stronger for male students, whereas the association between learning process support and emotional engagement was stronger for female students. A longitudinal study of Canadian high school students found that girls perceived more relatedness satisfaction than boys

in the context of unspecified subjects (Ratelle & Duchesne, 2014). Female students and students with higher interdependent self-construal tended to be more motivated than male students (Tanaka, 2022). Overall, girls have been shown to be more susceptible to relatedness support than boys and thus more engaged with SRL.

Accordingly, in this study, it is hypothesised that female students will score higher on relatedness support measures than male students (H2c) and that gender will moderate relatedness support when predicting the relationship between AI knowledge and SRL (H3c).

In sum, three main hypotheses are

- AI knowledge will be associated with SRL (H1);
- Female students will perceive more needs satisfaction for autonomy, competence and relatedness than male students (H2a H2b, H2c);
- The gender will moderate needs support for autonomy, competence and relatedness when predicting the relationship between AI knowledge and SRL (H3a, H3b, H3c).

Method

Participants and Research Procedure

The participants were from three middle schools in Hong Kong with average academic performance standards and socioeconomic status, and they ranged in age from 12 to 14 years. All of the participants were Chinese second language English learners and had acquired a basic knowledge of AI. Accordingly, Grade 9 students were chosen because they all received AI learning as a Grade 7 - 9 AI curriculum were designed and implemented in the schools last three year (Xia et al., 2022).

The participants took a 20-minute AI test before learning how to use an AI-based chatbot at school. Over the course of 5 days, they had the option to select one of eight themes, including hello, hotel, conversations, and meetings. Students can make conversations with chatbot by texting or speaking. On the last day, they had 20 minutes to complete the questionnaire. This learning arrangement had no direct connection with the research design. Nonetheless, the students may have felt unfamiliar learning with chatbots at school because the technology was still relatively new. Thus, the purpose of arranging this learning was to ensure that all of the participants had experience learning from a chatbot so that they could understand and answer the questions in the questionnaire.

To choose the chatbot for this study, the corresponding author and three teachers from the schools in the course screened and tested commercially available conservational chatbots. The three teachers rated the chatbots independently, and the corresponding author consolidated the teachers' scores. The chatbot chosen got the highest rating. The chatbot offered eight themes including hello, hotel, conversations, and rental cars. The students can choose any of the eight topics during classroom lessons dedicated for self-regulated learning. They can set their own learning interface. The chatbot also offered various functions including voice input, handwritten typing and voice dialogue. The students can communicate with the chatbot by speaking, listening, reading and writing. AI speech offers the students the opportunity to learn through speaking and listening, and AI read offers authentic conversations.

Questionnaire and Test

The questionnaire is used to collect student demographic information (e.g., gender), and 5 measures: perceived autonomy, competence, relatedness, SRL, and satisfaction with the chatbot.

Each measure consisted of four items that the students answered on a 5-point Likert scale. All the items are attached in the index. The students were also assessed on their basic knowledge of using AI. Three teachers were selected to check the items to ensure that the language and wording could be understood by middle school students.

The items for perceived autonomy and competence satisfaction, as facilitated by the chatbot, were adapted from Hew and Kadir (2016), see the Appendix. Their validity was demonstrated by Chiu (2021, 2022) among students from a similar demographic background to the participants in this study. The items for perceived autonomy satisfaction had an original reliability of $\alpha = .82$. An example is 'I feel like I can make a lot of input in deciding how I use the chatbot in learning'. The reliability of the items for perceived competence was $\alpha = .71$. An example is 'I think I am pretty good at learning with the chatbot'.

The items for perceived relatedness satisfaction were adapted from Furrer and Skinner (2003), and their reliability was $\alpha = .86$. An example is 'When I learn with the chatbot, I feel supported (changed to comfortable/important/valued)'.

The items measuring SRL were adapted from Sha and colleagues (2012), with $\alpha > .70$. An example is 'When learning English with the chatbot, I normally set learning goals for myself so that I can decide how and what I want to learn'.

The test of the students' AI knowledge comprised ten questions. An example is 'Which one is an AI application?'. The maximum possible score was ten.

Results

Analytics Approach

In response to RQ2, the differences between boys and girls were assessed by independent-samples *t* tests for each SDT need and Cohen's *d* was used to identify the effect size.

To answer RQ1 and RQ3, each SDT need was plotted to visualise its relationship with SRL. Multiple linear regression models were fitted without interaction terms for each SDT need to examine the relationship between SDT needs and SRL. Nonlinearity was tested by adding quadratic terms to each SDT need.

Descriptive Statistics

Table 1 shows the descriptive statistics. reliability, and correlation matrix for all variables. They showed that the data are normally distributed and all the All correlations are significant ($p < .001$). These indicate the data is good for the following analyses.

Gender differences in SDT needs, AI knowledge, and SRL

Table 2 indicates that the girls perceived higher satisfaction for all three needs compared with the boys. Following Cohen (1988), the effect sizes for the gender differences were medium for autonomy ($d = .58$), small for competence ($d = .40$), medium for relatedness ($d = .62$), large for SRL ($d = .95$), and medium for AI knowledge ($d = .70$).

Table 1. Descriptive Statistics, Reliability, and Correlation Matrix for All Variables

Item	M	SD	Skewness	Kurtosis	1	2	3	4	5	6
1 SRL	3.79	1.01	-0.21	-0.17	-					
2 Autonomy	3.74	.95	-0.16	-0.55	.473	-				
3 Competence	3.67	.91	-0.16	-0.40	.494	.463	-			
4 Relatedness	3.49	.84	-0.08	-0.38	.375	.410	.442	-		
5 AI	7.30	2.04	0.17	-0.73	.443	.566	.475	.419	-	
6 Gender	-	-	-	-		.280	.197	295	.334	-

Note. N = 323. All correlations are significant ($p < .001$).

Table 2. Comparison of Dependent Variables between Female and Male Students

	Girls (n = 157)		Boys (n = 166)		*T*	*df*	Cohen's *d*
	M	SD	M	SD			
Autonomy	4.01	.90	3.48	.92	-.53***	321	.58
Competence	3.86	.91	3.50	.87	-.357***	321	.40
Relatedness	3.75	.89	3.25	.71	-.495***	321	.62
SRL	4.24	.96	3.37	.87	-8.57***	321	.95
AI	7.99	1.95	6.64	1.92	-1.34***	321	.70

Note. *** $p < .001$.

How does gender interact with need satisfaction and AI knowledge when predicting SRL?

Multiple linear regression models were constructed to test the research hypothesis that each SDT need is moderated by gender and AI knowledge. Post hoc probing of significant moderating effects was conducted. A Bonferroni correction was estimated to maintain an alpha level of .05 in moderated multiple regression (Dawson & Richter, 2006) when a three-way interaction term was significant (Miller, 1981).

Table 3 shows the relationships between AI knowledge and SRL as moderated by gender and autonomy in predicting SRL (B = -.091, $p < .05$). Three-way moderation effects were found (see Figure 3). Autonomy provided a larger incremental contribution beyond AI knowledge and gender in predicting SRL (△R2 = .093). Table 5 shows that the slope for students with high-AI knowledge differed significantly for girls and boys in predicting SRL. The same was true for students with low-AI knowledge. That is, as autonomy increased, the effects of AI knowledge on SRL increased for girls, especially girls with low-AI knowledge.

Table 3. Relationships between AI Knowledge and SRL as Moderated by Gender and Autonomy

Variable	SRL			
	Model 1		Model 2	
	B	SE	B	SE

Intercept	3.445***	.070	3.496***	.071
AI	.119***	.035	.039	.038
Gender	.647***	.101	.735**	.107
AI × Gender	.098*	.049	.059	.055
Autonomy			.269**	.086
AI × Autonomy			-.031	.055
Gender × Autonomy			.009	.120
AI × Gender × Autonomy			-.091*	.045
Model R^2	.2964		.3898	
$\triangle R^2$			.0934	

Note: * p < .05, ** p < .01, *** p < .001.

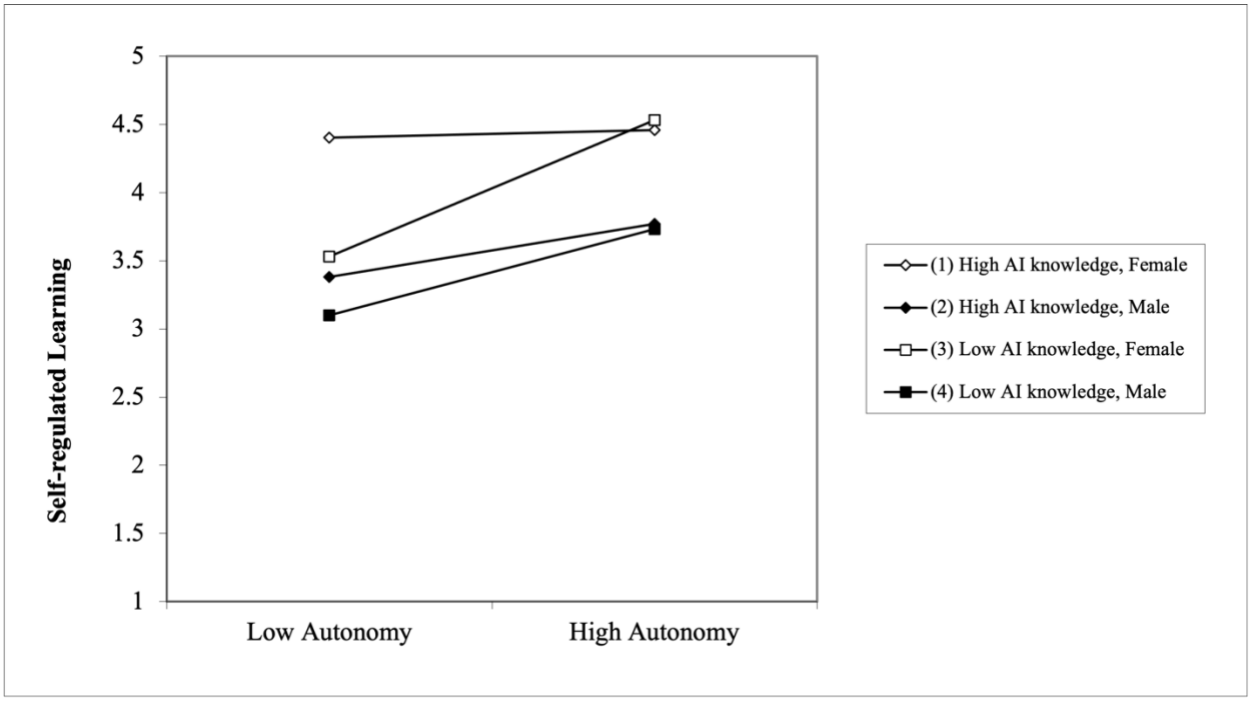

Figure 3. Relationships between autonomy and SRL at low and high AI knowledge for both girls and boys (high and low autonomy are the mean and +/- SD from the mean).

Table 4 shows the relationships between AI knowledge and SRL as moderated by gender and competence in predicting SRL (B = -.124, p < .001). Three-way moderation effects were found

(see Figure 4). Competence provided a larger incremental contribution beyond AI knowledge and gender in predicting SRL (△R2 = .1473). Figure 4 shows that the slopes of those with high-AI knowledge differ significantly for girls in predicting SRL. Similarly, the slopes for students with low-AI knowledge differ significantly for boys and girls. That is, as competence increased, the effects of AI knowledge on SRL increased for girls, especially those with low-AI knowledge.

Table 4. Relationships between AI Knowledge and SRL as Moderated by Gender and Competence

Variable	SRL			
	Model 1		Model 2	
	B	SE	B	SE
Intercept	3.445***	.070	3.462***	.067
AI	.119***	.035	.055	.036
Gender	.647***	.101	.744**	.098
AI × Gender	.098*	.049	.028	.050
Competence			.272**	.083
AI × Competence			-.013	.035
Gender × Competence			.221*	.111
AI × Gender × Competence			-.124***	.045
Model R^2	.2964		.4437	
$\triangle R^2$			.1473	

Note: * p < .05, ** p < .01, *** p < .001.

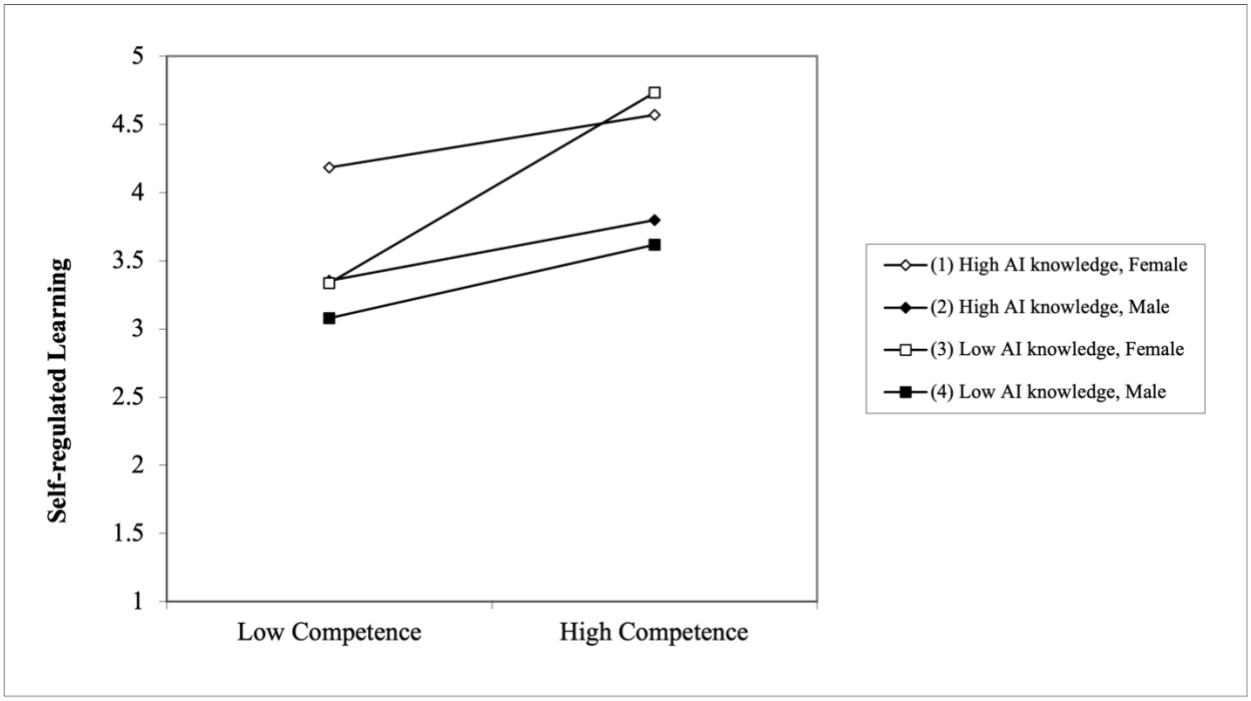

Figure 4. Relationships between competence and SRL at low and high AI knowledge for both male and female students (high and low competence are the mean and +/- SD from the mean).

Table 6 shows the relationships between AI knowledge and SRL as moderated by relatedness. The three-way interaction terms (gender × AI knowledge × relatedness) in predicting SRL were not statistically significant. However, when parsimonious models with two-way interaction terms were fitted, the two-way interaction terms between gender and relatedness were statistically significant ($B = .260$, $p < .05$) in predicting SRL. The moderation effects are illustrated in Figure 5. The difference in the slope of the lines represents the moderation. The slope is greater for girls than boys at both high and low levels of AI knowledge. That is, as relatedness increased, regardless of the level of AI knowledge, girls showed greater SRL than boys. In addition, relatedness provided a slight contribution beyond gender and AI knowledge in predicting SRL ($\triangle R2 = .0729$).

Table 5. Tests of Simple Slopes of SRL on Autonomy and Competence

	Pair of slopes	Slope difference	*t*	Bonferroni's *p*
Autonomy	High-AI girls vs high-AI boys	-.177	-25.91*	.000
	High-AI girls vs low-AI girls	-.497	-.62	.134
	High-AI boys vs low-AI boys	-.125	-.15	.220
	Low-AI girls vs low-AI boys	.195	7.69*	.000
Competence	High-AI girls vs high-AI boys	-.033	-4.89*	.000
	High-AI girls vs low-AI boys	-.560	-.70	.122
	High-AI boys vs low-AI boys	-.052	-.06	.238
	Low-AI girls vs low-AI boys	.475	-18.72*	.000

Note. N = 323. The Bonferroni correction was applied. *p < .013.

Table 6. Relationships between AI Knowledge and SRL as Moderated by Gender and Relatedness

Variable	SRL			
	Model 1		Model 2	
	B	SE	B	SE
Intercept	3.445***	.070	3.488***	.070
AI	.119***	.035	.095**	.036
Gender	.647***	.101	.688***	.102
AI × Gender	.098*	.049	.042	.051
Relatedness			.068	.102
AI × Relatedness			-.067	.045
Gender × Relatedness			.260*	.129
Model R^2	.2964		.3653	
$\triangle R^2$			.0729	

Note: * p < .05, ** p < .01, *** p < .001.

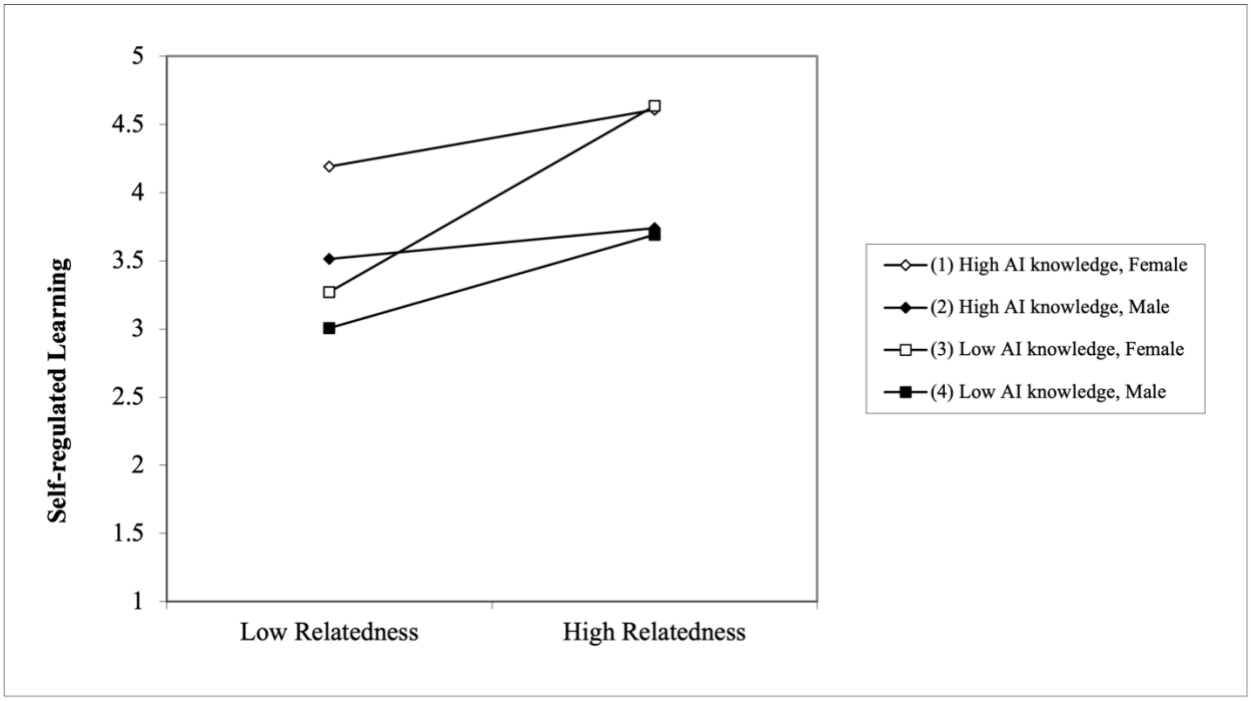

Figure 5. Relationships between relatedness and SRL at low and high AI knowledge for both male and female students (high and low relatedness are the mean and +/- SD from the mean).

Discussion

A full examination of all three hypotheses resulted in four major findings. First, AI knowledge was positively related to SRL with a chatbot (RQ1, H1). Second, gender moderated the association between AI knowledge and SRL such that the relation between AI and SRL was stronger among girls (RQ3, H3). Third, gender moderated the two-way interaction between satisfaction of the needs for competence and relatedness and SRL (RQ3, H3). Fourth, a three-way interaction was found with the needs for autonomy and competence but not with the need for relatedness (RQ3, H3). Compared with boys, girls with stronger AI knowledge perceived greater satisfaction of the need for autonomy and competence, and girls with weaker AI knowledge perceived higher autonomy.

These findings contribute to the literature in several ways. First, they reveal a positive association between AI knowledge and SRL with chatbots, providing potent support for previous findings that learners' AI efficacy or prior knowledge of AI positively influences SRL in a digital environment (Chiu, 2017, Chiu et al., 2022; Ong & Lai, 2006; Roca et al., 2006; Yang et al., 2018) (H1). Many studies have stressed the importance of digital literacy/competence in non-AI environments (Anthonysamy et al., 2020; Audrin & Audrin, 2022; Chan et al., 2017; List et al., 2020; Polizzi, 2020), this study responded to their appeals by showing that computer efficacy also elicits SRL in AI environments.

Second, this study examined the two-way interaction whereby gender moderated the relationships between need satisfaction and SRL, thus providing a deeper understanding of gender differences in need satisfaction and SRL with a chatbot. Our results found that girls perceived higher competence and relatedness and increased SRL with the chatbot (H2a, H2b, H2c). According to SDT, individuals who have their three needs satisfied are more likely to be competent in SRL with a chatbot. Our results support the view that boys with less support for competence and relatedness are more vulnerable during SRL with a chatbot and are therefore eager to receive more support for these needs from their teachers or the chatbot. In other words, boys may not perceive competence and relatedness immediately or quickly, even when facing a high level of demotivation. Moreover, gender did not moderate the relationship between autonomy satisfaction and SRL, i.e., girls and boys perceived the same level of autonomy. This result contradicts the findings of previous studies indicating that girls perceive more autonomy support from their teachers than boys do (Cheon et al., 2012; Kındap-Tepe & Aktaş, 2021; Lam et al., 2012; Lietaert et al., 2015; Mandigo et al., 2008; Vantieghem & Van Houtte, 2015). These studies were conducted in a non-conversational face-to-face or online context, unlike the conversational context of this

study. Therefore, the contradictions could be due to the different context. The results of this study are in accordance with a longitudinal study of Canadian high school students that found that girls felt more satisfied with their competence than boys in the context of unspecified subjects (Ratelle & Duchesne, 2014). A possible reason is that girls prefer to text via instant messaging systems or are more expressive in digital environments (Hsi & Hoadley, 1997; Kimbrough et al., 2013; Luor et al., 2010), as they prefer computer-mediated communication to face-to-face discussion (Prinsen et al., 2007).

The final and most important implication of our findings is that they fill a research gap by addressing the gender difference in the SDT and TAM models. The results thus contribute to the field by exploring the three-way interaction of gender, AI knowledge, and the satisfaction of each three needs with SRL using a chatbot. The interactions were found to be significant only for autonomy and competence satisfaction (H3a, H3b). Table 5 shows that the slopes of low-AI students were significantly different for girls and boys, and the *t* value was positive, indicating that girls with less AI knowledge need more support for autonomy than boys with the same AI knowledge during SRL with a chatbot. This result can be explained by previous findings that girls are more influenced by psychological support than boys and that support for the learning process is more strongly associated with emotional engagement for girls than boys (Bru et al., 2021; Goodenow, 1993; Ratelle & Duchesne, 2014; Ryan, Stiller, & Lynch, 1994). These results also indicate that autonomy support is more important for girls with low AI knowledge as they have less self-efficacy and confidence than boys in using PCs and communication technology (Ong & Lai, 2006; van Braak, 2004).

Conclusions

Theoretical Contributions

The first major finding contributes to the literature on SDT by indicating that psychological need satisfaction can affect SRL with AI (Ryan & Deci, 2020). Most related SDT-based studies have highlighted the importance of teacher support in both face-to-face and technological learning environments, i.e., how teachers support student learning both with and without technology (Bedenlier et al., 2020; Chiu, 2022; Chiu et al., 2021; Xie & Ke, 2011). However, few SDT-based studies have examined the moderating effect of psychological needs on SRL in a technology-based learning environment. Therefore, this study fills this gap and confirms the effectiveness of SDT provided by technology for students' SRL.

The second theoretical contribution, which is driven by the last three findings, concerns psychological need support in a technological learning environment. This study found that students' SRL with AI can be engaged by supporting their needs for autonomy, competence, and relatedness. This indicates the importance of psychological needs in technological learning environments. However, most studies of AI in education have focused on cognitive outcomes and adaptive learning rather than the effects of psychological needs on SRL in AI-supported environments (Salas-Pilco, 2020). This study fills this research gap and suggests that psychological needs should be considered in an AI-supported learning environment.

Practical Suggestions

This study offers three practical suggestions for instructional designers and teachers to satisfy the three needs of students to support SRL in a technological learning environment. The first suggestion is for teachers to use AI-supported learning resources to engage students' SRL because this study confirms that this technology can meet the students' three needs in similar ways that a

teacher can (Chiu, 2022; Lietaert et al., 2015; Vansteenkiste et al., 2009). Teachers can choose different technological resources according to the students' AI knowledge levels (Kintsch, 1980). Furthermore, teachers should realise that as some intelligent technologies are still in development (Chew & Chua, 2020; Palasundram et al., 2019), such as the chatbots in this study, teachers could organise group learning to provide opportunities for students to interact, thus satisfying their relatedness needs (Liu et al., 2014; Skinner et al., 2008; Young, 2005). Current chatbot is designed with the assumption of interaction between machine and individual user. Accordingly, students can benefit from support for their three needs provided by the technological learning environment under teacher guidance.

The second suggestion for teachers is to pay attention to students' needs for autonomy and competence when catering to gender differences in learning with chatbots. It seems that chatbots provide more autonomy and competence support for girls than boys. This may have resulted from the subject domain in this study, as gender differences in language education may have led to this result. Girls have been reported to perceive a greater vocabulary and capacity when learning languages (Iwaniec, 2019; Lee & Kim, 2014).

The final suggestion is to develop an AI-related learning environment to support students' psychological needs. In designing and developing the environment, SDT should be used as a guide for creating effective AI educational tools. In designing chatbots for SRL, the responses could give more hints or word recommendations to boys than to girls. We suggest that AI developers should take into account the gender differences in need satisfaction when designing AI chatbots for SRL.

Limitations and Future Research Directions

This study found that psychosocial support can moderate students' SRL in an AI-supported learning environment. Nevertheless, four limitations of this study should be noted. First, this study confirms that AI knowledge influences SRL with AI-based chatbots. To further understand this association, more studies are needed using a variety of AI technologies such as computer vision and speech. Second, the participants were all Grade 9 students. According to Chiu (2021), education level influences the effects of digital support on learning. Therefore, a comparative study is needed to assess how need satisfaction varies at different education levels. Third, studies with a longitudinal research design are recommended to explore how AI supports the needs of both girls and boys over the long term, as SRL is a lengthy learning process. Finally, quantitative analysis has revealed various relationships in the proposed model but has failed to explain the reasons. A follow-up qualitative study is recommended to further understand how gender and need satisfaction affect the relationships between AI knowledge and SRL.

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- **Availability of supporting data**
  - The datasets used for the current study are available from the corresponding author on reasonable request.
- **Competing interests**
  - This study got ethical clearance from the author's university.
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Appendix

Perceived autonomy

I feel like I can make a lot of input in deciding how I use the chatbot in learning.

I feel a sense of freedom when using the chatbot.

I have many opportunities with the chatbot to decide for myself how to learn.

I have a say regarding what input I want to learn with chatbot.

Perceived competence

I think I am pretty good at learning with the chatbot.

I have been able to learn interesting new knowledge with the chatbot.

I feel a sense of accomplishment from learning with the chatbot.

I am pretty skillful at learning with the chatbot.

Perceived relatedness

When I learn with the chatbot, I feel supported.

When I learn with the chatbot, I feel comfortable.

When I learn with the chatbot, I feel important.

When I learn with the chatbot, I feel valued.

Self-regulated learning

When learning English with the chatbot, I will normally set learning goals for myself so that I can decide how and what I want to learn.

When learning English with the chatbot, I will normally try to identify the knowledge that I do not understand well.

When learning English with the chatbot, I will normally ask myself questions to help me focus on what to study.

When I am not sure about any English language, I will go back and try to figure it out on my own using the chatbot.