The Effect of Teachers' Support on Learners' Online Self-Regulated Learning: Mediating Analysis Based on Self-Efficacy

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Abstract—In the Internet era, as more and more online education platforms are launched, the application of online learning will become more and more popular. The learner's online self-regulated learning is not only the learner's self-assessment of the learning effect, but also the learners' motivation for further learning. Therefore, using the structural equation model as an analytical tool, this paper studies the influencing factors of learners' online self-regulation learning from two aspects of teachers' support and self-efficacy, in order to understand the mechanism of related influencing factors. The findings show that learners' online self-regulated learning is jointly influenced by teachers' support and learner self-efficacy, wherein self-efficacy has a significant direct effect on learners' online self-regulated learning. Teachers' support has an indirect effect on learners' online self-regulated learning through the mediating effect of self-efficacy.

Keywords—teachers' support, self-efficacy, online learning, self-regulated learning

1 Introduction

Online teaching is an important part of higher education informatization, and it has also become a new teaching method in higher education [1]. The online learning in the new era integrates sharing, interaction and co-creation. It is an online learning place with the characteristics of orientation, openness and connectivity. It is the key to realizing "everyone can learn, can learn everywhere, and can learn from time to time", and it is also an important entrance to interactive teaching and learning from the perspective of personalized and precise teaching analysis. Online learning has changed the traditional way of education and learning, making educational resources more convenient and comprehensive for people to use. The online learning platform integrates the connectivity of social networks, the convenience of interacting with domain experts, and the freedom to obtain network resources, so that hundreds of learners can actively participate in self-organization according to different learning goals.The concept of self-efficacy was first put forward by American psychologist Bandura, who believed that self-efficacy is

a subjective judgment of whether one can successfully carry out a certain achievement behavior. Online learning self-efficacy is the specific application of self-efficacy in the field of online learning, which mainly refers to a subjective judgment of individuals on their ability to use computers, network information resources or network communication tools, and online learning platforms to complete learning tasks.

However, there is no clear conclusion about the relationship between teachers' support, self-efficacy and learners' online self-regulated learning. Compared with traditional learning methods, online learning can not only provide learners with rich learning resources, but also enable learners to learn freely without the constraints of time and space, but its educational quality is also unsatisfactory. Due to the diversification of learning resources, it is difficult for online learners to formulate their own learning plans and goals, and they cannot freely monitor their own learning process and adopt effective learning strategies, resulting in continuous lack of motivation for learning and lack of effective learning reflection. The problem of low autonomy has caused many online learners to be in the predicament of self-regulated learning. In a word, online teaching makes teachers and learners "separate in time and space", which easily leads to the separation of teaching interaction and teaching behavior, which brings great challenges to teaching activities and learners' learning activities [2]. Therefore, it is necessary to explore the mechanism of teachers' support and self-efficacy on learners' online self-regulated learning under the specific background of online teaching.

2 Research hypothesis

At present, a large number of academic literatures have explored the influencing factors of learners' online self-regulated learning from different perspectives. Li (2019) constructed a SEM model of the relationship between learners' demographics, SRL strategy use, perceived learning and satisfaction in MOOCs and found that satisfaction can be determined by learners' knowledge level, the number of online courses they have attended in the past, the use of SRL policies and perceptual learning [3]. Cerezo (2019) proposed that interventions aimed at improving academic self-regulation must take into account the importance of motivational variables and their relationships to improve the use of self-regulation strategies. The study mainly analyzed the relationship between the training of self-regulation learning strategies and these Increased knowledge of strategies, self-efficacy in using these strategies and their perceived utility, and their effective application in academic learning tasks [4].

Kryshko et al (2022) investigated the relationship between motivation-regulated self-efficacy and the three dimensions of academic research satisfaction expectations, value and cost components of motivation and found motivation-regulated self-efficacy as an important but neglected components that participate in effective motivational regulation processes [5]. Through years of online learning exploration and continuous follow-up surveys on online platforms, as well as interviews with experts who study the process and effects of online education, this paper summarizes the factors that affect learners' online self-regulated learning as teachers' support, self-efficacy (self-efficacy of learning ability, self-efficacy of learning determination, self-efficacy of learning technology) and other factors.

2.1 Teachers' support

According to social cognitive theory, online learning is rooted in the context of socialization, and its process is clearly influenced by social support. In online learning, teachers' support is an important social support factor that affects learners' self-efficacy [6]. Teachers' support learners by encouraging them, taking the time to help and support them, treating them fairly, and giving them opportunities to make choices, and learners who perceive teachers' support are more motivated and perform better online. The support of teachers in online learning is mainly reflected in three aspects: First, to enhance the autonomy of learning, the independent support provided to learners in the aspects of activity design, content selection and problem solving; The second is to provide online learners with emotional support such as attention, motivation and praise [7]; The third is to provide online learners with cognitive support such as learning challenges, learning strategy guidance, learning resources and tools. Teachers' support will be measured in terms of autonomous support, emotional support, cognitive support, etc. Teachers' support reflects teachers' concern, trust and positive evaluation of learners, while academic self-efficacy is a subjective self-judgment of learners' interaction with the environment, and is the result of interaction with the environment. Research shows that teachers improve learners' self-efficacy by providing supportive feedback, which enables learners to better achieve self-regulated learning processes. Based on this, this paper proposes hypotheses H1, H2, H3, and H4.

H1: Teachers' support has a significant positive effect on the self-efficacy of learning ability.
H2: Teachers' support has a significant positive effect on the self-efficacy of learning determination.
H3: Teachers' support has a significant positive effect on the self-efficacy of learning technology.
H4: Teachers' support has a significant positive effect on online learners' self-regulated learning.

2.2 Self-efficacy

The concept of self-efficacy was first proposed by American psychologist Bandura in 1977, which believes that self-efficacy is an individual's confidence in his ability to complete a certain task or work [8]. The impact of self-efficacy on individuals is mainly reflected in four aspects: behavioral choice, motivational effort, cognitive process, and emotional process. Learning self-efficacy refers to the self-confidence evaluation of learners on whether they can use their abilities to complete learning tasks [9].

Improving online learners' self-efficacy and promoting learners' learning motivation are the key factors for online learners' self-regulated learning. Self-efficacy is divided into self-efficacy of learning ability, self-efficacy of learning determination and self-efficacy of learning technology. Among them, the self-efficacy of learning ability is measured with aspects such as "I am sure that I can understand the content of this course", and the self-efficacy of learning determination is measured with aspects such as "If I don't want my grades to be too bad, I can do it", etc. The self-efficacy of

learning technology is measured in terms of "I am able to use the platform and tools to better accomplish my learning tasks". Based on this, this paper proposes hypotheses H5, H6, H7.

H5: The self-efficacy of learning ability has a significant positive impact on online learners' self-regulated learning.
H6: The self-efficacy of learning determination has a significant positive effect on online learners' self-regulated learning.
H7: The self-efficacy of learning techniques has a significant positive effect on online learners' self-regulated learning.

2.3 Self-regulated learning

Self-regulated learning was first proposed by Zimmerman, which mainly refers to the process that learners, as active participants in metacognition, motivation and behavior, actively initiate learning, self-guide and use specific strategies to complete academic goals [10]. The definition of self-regulated learning that is more recognized by the academic community is: the process of learners taking the initiative to adopt a series of behavioral adjustments in order to complete specific learning tasks during the learning process. The various strategies adopted also include self-evaluation and reflection after learning, which are mainly reflected in multiple elements such as goal establishment, self-motivation, strategy use, self-monitoring, self-evaluation and reflection [11].

It has several notable features: highlighting the subjectivity of learners, emphasizing the integration of learning elements, emphasizing the autonomy of the learning process, and endogenous power and drive [12]. In this study, self-regulated learning is the main dependent variable, and other variables will directly or indirectly affect this factor. Self-regulated learning will be achieved through "I will set my own goals during online learning", "I like the content of online learning even if it is challenging", "I will often ask mastery questions during online learning to help me master the learning content", "I will adjust the learning progress in time according to the learning situation", "When I encounter problems in learning, I will find a way to ask for help", "At any stage of the course study, I will evaluate whether I have achieved the expected goals" and other aspects [13].

3 Questionnaire survey and data analysis

3.1 Questionnaire design and data collection

MOOC (Massive Open Online Course) is a typical online learning platform that can provide learners with free high-quality learning resources. MOOCs have attracted many learners to participate in course learning, and learners exchange and discuss course content and share resources in course discussion areas. Teachers can use the MOOC platform to assist course teaching, and provide learning support for learning through the online discussion space of the course, such as assisting learners in arranging study plans, encouraging learners' learning confidence through communication, and answering learners' difficulties in learning and technical problems. Since most MOOC

platforms provide free learning resources, the number of learners who use MOOCs for learning is relatively large, and it is typical and representative to use this platform as an example to conduct a learner survey [14]. Based on theories such as self-regulated learning, this research investigates MOOC platform learners and expects to draw meaningful conclusions through data analysis.

This paper uses a questionnaire survey method. The questionnaire design contains two parts: the first part is the personal basic information of online learners, such as age, gender, education, the use of MOOC platform, online learning courses and course completion status, etc.; the second part , according to the previous hypothesis, we measure the teachers' support, self-efficacy and self-regulated learning in the online learners' learning process, and the scales are designed using the Likert five-point measurement method. In order to ensure the validity and reliability of the scale, the mature scales of related research at home and abroad were referenced in the scale design. On this basis, questionnaires were distributed among learners participating in online learning, and a total of 284 valid questionnaires were collected. Harman's test was used to test for common method bias [15]. The results showed that there were 5 factors with eigenvalues greater than 1, which explained 72.43% of the variance, and the first factor explained a critical value of 40% of the variance. Therefore, there is no serious common method bias in this study.

3.2 Reliability and validity analysis

Since this study is an exploratory study and the sample size is relatively small, SmartPLS 3.0 was used for reliability and validity analysis, model construction and hypothesis validation. First, the reliability and validity of the recovered data were analyzed, and the analysis results are shown in Table 1.

Table 1. Reliability and validity analysis results

	CA	**AVE**	**Teachers' Support**	**Self-Efficacy of Learning Ability**	**Self-Efficacy of Learning Determination**	**Self-Efficacy of Learning Technology**	**Self-Regulated Learning**
Teachers' support	0.837	0.742	0.861				
Self-efficacy of learning ability	0.791	0.649	0.267	0.806			
Self-efficacy of learning determination	0.896	0.814	0.267	0.676	0.902		
self-efficacy of learning technology	0.930	0.822	0.297	0.312	0.271	0.907	
Self-regulated learning	0.939	0.887	0.218	0.686	0.826	0.376	0.942

3.3 Reliability analysis

First, the overall reliability of the research questionnaire was tested by CA (Cronbach's Alpha) value. After the results obtained by exploratory factor analysis, the reliability of the five latent variables was analyzed by the CA reliability coefficient test. The higher the reliability coefficient CA value (closer to 1) means the better of internal consistency of the scale. It can be seen from Table 1 that the reliability coefficients of teachers' support, self-efficacy of learning ability, self-efficacy of learning determination, self-efficacy of learning technology and self-regulated learning are 0.837, 0.791, 0.896, 0.930 and 0.939, all above 0.7. This is clearly greater than the critical value. Generally speaking, a Cronbach's Alpha value greater than 0.7 indicates credibility, which indicates that each item has a strong correlation with the dimension to which it belongs, and the internal consistency of the scale is good.

3.4 Validity analysis

Validity measures the degree to which a measurement tool can accurately measure what it needs to measure. The more consistent the measurement results, the higher the validity; otherwise, the lower the validity. In this paper, the structural validity of the data is measured, that is, to measure whether each variable is suitable for factor analysis, so KMO and Bartlett tests are carried out. Bartlett test is used to test whether the correlation coefficients of the items are different and related. If the test result is less than 0.01, the null hypothesis that the correlation matrix is a unit matrix can be rejected, indicating that there is a significant correlation between the variables [16]. The scale of this study basically refers to mature scales at home and abroad, and pre-investigation was conducted before the formal investigation, and the content was adjusted according to the results of the pre-investigation. It can be considered that the content validity of the measurement model in this study is good. The AVE in Table 1 is the average extraction variance value [17]. According to the relevant literature, if the AVE is greater than 0.6, it can be considered that the scale has good convergent validity. The convergent validity of the measurement model is considered to be ideal. The correlation coefficients of all latent variables on the off-diagonal line are much smaller than the square root of the AVE value on the diagonal line, which indicates that the latent variables have high discriminant validity with other latent variables [18].

3.5 Structural equation model

Through the reliability and validity test, it can be determined that the preconditions of this study have been met, and the sample can be further analyzed. According to the aforementioned construct model, this study uses the structural equation software SmartPLS3.0 to analyze the structural equation model established in this paper, and the results are shown in Figure 1.

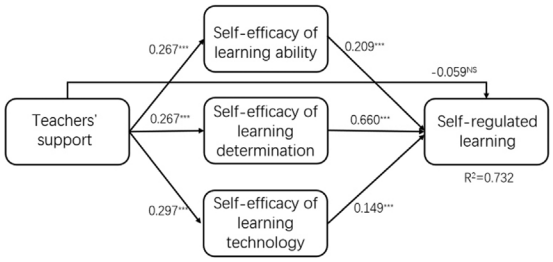

Fig. 1. Key variable path analysis

Note: *** means P less than 0.001, ** means P less than 0.01, * means P less than 0.05.

In the PLS path analysis, it is calculated that teachers' support has a significant impact on the self-efficacy of learning ability, the self-efficacy of learning determination, and the self-efficacy of learning technology (0.267, P<0.001; 0.267, P<0.001; 0.297, P<0.001), H1, H2, and H3 are confirmed. Self-efficacy of learning ability, self-efficacy of learning determination, self-efficacy of learning technology have a significant impact on self-regulated learning (0.209, P<0.001; 0.660, P<0.001; 0.149, P<0.001), H5, H6, and H7 are confirmed; the effect of teachers' support on self-regulated learning is not significant (0.075, P>0.05), and H4 is not supported.

In this paper, the method of structural equation modeling is used to test the research hypothesis, and the model estimation method is the maximum likelihood estimation method [19]. Taking teachers' support as the predictor variable, self-regulated learning as the outcome variable, and self-efficacy of learning ability, self-efficacy of learning determination, self-efficacy of learning technology as mediating variables. This paper uses the parameters estimated by the bootstrapping algorithm to verify whether the mediation effect is significant. As shown in Table 2, from the T-test value, all are less than 0.01, and its 95% confidence interval does not contain 0, which indicates that between teachers' support and self-efficacy of learning ability, self-efficacy of learning determination, self-efficacy of learning technology played a mediating role.

Table 2. Mediating effect test

	Point Estimation of Indirect Effects	**Bootstrap 1000 Times**			**95% Confidence Interval**	
		SE	**T**	**P**	**Low**	**Upper**
Teachers' support –> self-efficacy of learning determination –> self-regulated learning	0.177	0.038	4.663	<0.001	0.112	0.253
Teachers' support –> self-efficacy of learning technology –> self-regulated learning	0.044	0.011	4.138	<0.001	0.025	0.067
Teachers' support –> self-efficacy of learning ability –> self-regulated learning	0.056	0.019	2.989	<0.01	0.026	0.099

From Figure 1, Table 2 and the results of the significance test of the mediation effect, it can be seen that teachers' support, self-efficacy of learning ability, self-efficacy of learning determination, self-efficacy of learning technology all have significant effects on online learners' self-regulated learning. Among them, the realization of teachers' support is an indirect effect, while the self-efficacy of learning ability, self-efficacy of learning determination, self-efficacy of learning technology are directly affected. Among all the influencing factors, the self-efficacy of the will to learn has the greatest influence on the self-regulated learning of online learners, and the indirect effect of the self-efficacy through the will to learn is the greatest.

4 Suggestions for improving self-regulated learning for online learners

4.1 Improve teachers' support

Learners' perceived teachers' support behaviors can affect their academic achievement motivation, which in turn has a lasting impact on learning. Constructivist psychologist Biggs believes that a better learning model is not passive acceptance, but an active construction of a learning paradigm. Learning is not an isolated process, but is constructed in the context of dynamic interaction between learning subject and object. The teacher expectation effect is the reflection of the influence of teacher object behavior on the cognitive and emotional level of the learners, and it must be regulated by the factors within the subject [20]. Therefore, educational institutions need to take a combination of material and spiritual methods to strengthen the willingness and motivation of teachers to support. Encourage learners to learn new learning skills and strategies through teachers' support, provide learners with feedback and personalized guidance on the learning process, support learners in developing skills in collaborative learning and interactive learning, and cultivate and drive learners to reflect on their learning abilities. The study found that both teachers' support and online learning self-efficacy were important factors affecting their online learners' self-regulated learning [21]. The online learning experience highlights the important role of existing teachers' support for learners' self-efficacy and online learners' self-regulated learning. In practice, teachers' support can drive the self-efficacy of online learners from the aspects of technical support, cognitive support and emotional support, provide them with various learning resources support, formulate individualized learning plans, conduct learning methods and skills guidance and Emotional feedback, etc. In the process of learning preparation, teachers can guide through goal setting, goal confirmation, expectations, etc [22]. During the implementation process, teachers can provide learning method guidance, process feedback and adjustment, spiritual power improvement, and answering questions. In the evaluation stage, learners' self-efficacy can be improved through organizational reflection process and effect evaluation.

4.2 Improve learners' self-efficacy

Learners' online learning self-efficacy is one of the important factors to promote self-regulated learning level. A good online learning environment can make college

learners adapt to the new teaching method of online teaching better and faster, reduce the frustration in the online learning process, and play an important role in improving the self-efficacy of online learning technology of college students. Based on this, schools should provide students with skills training and guidance in the use of information technology and online teaching platforms, improve learners' information literacy, the ability to use learning tools, and reduce the setbacks caused by technical difficulties in the online learning process of college students. At the same time, schools should also provide learners with training in online learning methods, so as to increase the knowledge base of learners in online learning in an all-round way. This can not only improve learners' online learning self-efficacy, but also improve their self-regulated learning level [23]. In addition to the provision of external infrastructure in terms of technology, emphasis should be placed on providing learners with specific guidance on online learning skills and learning models.

4.3 Promote the formation of self-regulated learning

In the process of learning, learners take the initiative to manage and take responsibility for learning, which is regarded as an inevitable path to achieve learning performance. Nowadays, the self-regulated learning of online learners is not ideal, so it is worth paying attention to how to promote the self-regulated learning of online learners [24]. In the context of education platformization and big data analysis, data analysis can be used to precisely intervene in online learners' self-regulated learning. The first is to fully mine the online learning data of learners, analyze the learning status and progress in detail, reflect the existing problems, analyze the deep-level influencing factors, and establish an early warning mechanism for online self-regulation learning. The second is to explore the means of self-regulation learning intervention in online learning, find out effective online self-regulation learning intervention paths, and find the best practice path.

5 Research deficiencies and research prospects

Based on the theory of self-efficacy, this study explores the conditional factors that generate self-efficacy in the process of online learning and the resulting factors that lead to self-efficacy. Taking the MOOC online education platform as an example, according to the recovered valid data, the reliability and validity were analyzed with Smart PLS3.0 software, and the structural equation model and hypothesis test results of the influence of self-efficacy on self-regulation learning were obtained. , and put forward corresponding suggestions from three aspects: teachers' support, self-efficacy and self-regulated learning. The biggest feature of this study is that it not only explores how self-efficacy affects continuous online self-regulation learning, but also explores the conditional factors that affect the production of self-efficacy. The conclusion has certain theoretical and practical significance. In addition, follow-up research can further explore the specific role of different mediating factors in the influence mechanism of learners' online learning self-efficacy on their online self-regulated learning. It is also possible to conduct further comparative research on the network autonomous learning

and learning in the online teaching environment, so as to provide more targeted basis and suggestions for promoting the improvement of the quality of online teaching in colleges and universities.

6 References

[1] Bao, W. (2020). COVID-19 and online teaching in higher education: A case study of Peking University. Human Behavior and Emerging Technologies, 2(2), 113–115. https://doi.org/10.1002/hbe2.191

[2] Bol, L., & Garner, J. K. (2011). Challenges in supporting self-regulation in distance education environments. Journal of Computing in Higher Education, 23(2), 104–123. https://doi.org/10.1007/s12528-011-9046-7

[3] Li, K. (2019). MOOC learners' demographics, self-regulated learning strategy, perceived learning and satisfaction: A structural equation modeling approach [J]. Computers & Education, 132(1), 16–30. https://doi.org/10.1016/j.compedu.2019.01.003

[4] Cerezo, R., Fernández, E., Amieiro, N., Valle, A., Rosário, P., & Núñez J. C. (2019). Mediating role of self-effificacy and usefulness between self-regulated learning strategy knowledge and its use [J]. Revista de Psicodidáctica, 24(1), 1–8. https://doi.org/10.1016/j.psicod.2018.08.001

[5] Kosovich, J., Fleischer, J., Grunschel, C., & Leutner, D. (2022). Self-efficacy for motivational regulation and satisfaction with academic studies in STEM undergraduates: The mediating role of study motivation [J]. Learning and Individual Differences, 93(12), 1–12. https://doi.org/10.1016/j.lindif.2021.102096

[6] Mercer, S. H., Nellis, L. M., Rebecca, S., et al (2011). Supporting the students most in need: academic self-efficacy and perceived teacher support in relation to within-year academic growth [J]. Journal of School Psychology, 49(3), 323–338. https://doi.org/10.1016/j.jsp.2011.03.006

[7] Cox, A., & Williams, L. (2008). The roles of perceived teacher support, motivational climate, and psychological need satisfaction in students'physical education motivation [J]. Journal of Sport & Exercise Psychology, 30(2), 222–239. https://doi.org/10.1123/jsep.30.2.222

[8] Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change [J]. Psychological Review, 84(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

[9] Lorsbach, A., & Jinks, J. (1999). Self-efficacy theory and learning environment research [J]. Learning Environments Research, 2(2), 157–167. https://doi.org/10.1023/A:1009902810926

[10] Moos, D. C., & Azevedo, R. (2008). Self-regulated learning with hypermedia: The role of prior domain knowledge [J]. Contemporary Educational Psychology, 33(2), 270–298. https://doi.org/10.1016/j.cedpsych.2007.03.001

[11] Schunk, D. H. (2005). Self-regulated learning: The educational legacy of Paul R Pintrich [J]. Educational Psychologist, 40(2), 85–94. https://doi.org/10.1207/s15326985ep4002_3

[12] Schmitz, B., & Wiese, B. S. (2006). New perspectives for the evaluation of training sessions in self-regulated learning: Time-series analyses of diary data [J]. Contemporary Educational Psychology, 31(1), 64–96. https://doi.org/10.1016/j.cedpsych.2005.02.002

[13] Roth, A., Ogrin, S., & Schmitz, B. (2016). Assessing self-regulated learning in higher education: A systematic literature review of self-report instruments [J]. Educational Assessment, Evaluation and Accountability, 28(3), 225–250. https://doi.org/10.1007/s11092-015-9229-2

[14] Allen, I. E., & Seaman, C. A. (2007). Likert scales and data analyses [J]. Quality Progress, 40(7), 64–65.

[15] Xu, Z. Z., & Qi, C. (2019). The relationship between teacher-student relationship and academic achievement: the mediating role of self-efficacy [J]. Eurasia Journal of Mathematics Science and Technology Education, 15(10), 1–7. https://doi.org/10.29333/ejmste/105610

[16] Alghamdi, A., Karpinski, A. C., Lepp, A., & Barkley, J. (2020). Online and face-to-face classroom multitasking and academic performance: Moderated mediation with self-efficacy for self-regulated learning and gender [J]. Computers in Human Behavior, 102, 214–222. https://doi.org/10.1016/j.chb.2019.08.018

[17] Gonzalez-Pienda, J. A., Fernandez, E., Bernardo, A., Núnez, J. C., & Rosario, P. (2014). Assessment of a self-regulated learning intervention [J]. Spanish Journal of Psychology, 17, 1–9. https://doi.org/10.1017/sjp.2014.12

[18] Yuan, D. C., & Yue, X. G. (2014). SVMR model for coal mine cost management prediction. Applied Mechanics and Materials, 484–485, 608–611. https://doi.org/10.4028/www.scientific.net/AMM.484-485.608

[19] Zhang, G., Yue, X.-G., Li, M.-X., & Chen, J.-X (2014). Biological opposite degree algorithm and its application in coal and gas outburst prediction. Journal of Chemical and Pharmaceutical Research, 6(6), 1756–1761.

[20] Guo, H. B., Yue, X. G., & Chen, X. W. (2014). Study of fuzzy mathematics in diseases diagnosis. Applied Mechanics and Materials, 608–609, 835–838. https://doi.org/10.4028/www.scientific.net/AMM.608-609.835

[21] Wang, X. C., & Yue, X. G. (2013). Algorithm of coal mine rescue robot model based on PSO and GEP. Applied Mechanics and Materials, 416–417, 739–742. https://doi.org/10.4028/www.scientific.net/AMM.416-417.739

[22] Zhang, G., Yue, X. G., Yang, J., Chen, J. X., Zhao, Z. Q., & Xie, X. L. (2013). Electromagnetic induction heating application in mining safety detection. Advanced Materials Research, 722, 528–531. https://doi.org/10.4028/www.scientific.net/AMR.722.528

[23] Wang, X. C., Yue, X. G., Ren, Q. G., & Zhao, Z. Q. (2013). Research on coal mine rescue robot model. Applied Mechanics and Materials, 340, 801–804. https://doi.org/10.4028/www.scientific.net/AMM.340.801

[24] Yue, X., Zhang, G., Ren, Q., Liao, W., Chen, J., Zhao, Z., & Xie, X. (2013). Research on sustainable mining engineering. Applied Mechanics and Materials, 340, 126–130. https://doi.org/10.4028/www.scientific.net/AMM.340.126

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