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Digital Educational Resources Configuration Model and Mechanisms for K-12 in China

Jihong DING[a], Huazhong LIU[b*], Mengsha WEN[c], Wenzheng YANG[d] & Bo JIANG[a]
[a] *School of Education Science and Technology, Zhejiang University of Technology, China*
[b] *School of Computer Science and Technology, Huazhong University of Science and Technology, China*
[c] *School of Computer Science and Software engineering, East China Normal University, China*
[d] *School of Information Technology, Yunnan Normal University, China*
*sharpshark_ding@163.com

Abstract: Traditional configuration model of digital educational resources (DERs) leads to digital divide. To achieve the public service equalization of DERs for K-12 in China, this paper proposes an "intra-regional co-construction and sharing, inter-regional sharing and exchanging" (IRCS&IRSE) model and three mechanisms. Firstly, the ratio of resource development fund to environment construction fund is dynamically regulated to improve the resource allocation efficiency. Secondly, determine resource purchase funds by users' feedback to improve the quality of DERs. Thirdly, determine schools' information environment construction fund by their utilization of DERs to better utilize the resources. Simulation experiment was conducted using the Vensim software, the result showed that the three mechanisms were all effective and they worked well for the public service equalization of DERs.

Keywords: Resources configuration; Digital learning environment; K-12; Performance improving

1. Introduction

It is well known that education is one of the most essential and fundamental parts for a country, and is even vital for an emerging country like China. However, the unbalanced development of economy in China results in the urban-rural economic gap and the regional development disparity. Traditionally, educational funds of K-12 schools in China are allocated depending on each county which is a regional administrative unit with uneven economy level. Hence, serious education imbalance emerges, and there is no doubt that only will the rational allocation of education resources that can this serious imbalance be solved. Under this circumstance, massive methods have been proposed to narrow this gap. This paper aims to optimize the resource utilization and improve the education quality by designing an "intra-regional co-construction and sharing, inter-regional sharing and exchanging" (IRCS&IRSE) model and three incentive mechanisms to achieve the co-construction and sharing of digital educational resources (DERs).

2. Literature Review

In the past few years, there are many scholars studied the serious education problem (Long, 2016; Cobb-Clark, 2016; Tao, 2016), and struggled to propose some adaptive and rational solutions. Therefore, plenty of methods have been proposed, such as the transferred-payment system in education (Wang, 2011)), offering some recommendations for resource allocation policies (Matthew R., 2017), etc. These methods indeed solve certain aspects of this problem, nevertheless, it appears that the status-quo is still not optimistic, which is reflected on continuous significant regional education informatization index gap. Fortunately, benefiting from the internet, people expect that there are some rosy changes happening in education resources fairness. The information and communication technology (ICT) brings in innovative solutions, which are completely different from the traditional measures, to bridge the educational gap (Sahoo, 2012). For example, worldwide

open course wares (OCW) and massive open online courses (MOOCs) projects promoted accessibility of DERs and fairness of education. It attracted Chinese government's attention, and the Ministry of Education of China stated that the government should encourage the development of high quality educational information resources and improve the public education service system. Thus, the equalization of basic public education services and fair education maybe realized steadily (The Central Committee of the Communist Party of China, & the State Council of China, 2010). Nevertheless, the development of high-quality digital educational resources addresses only one part of the educational problem (Huang, & Spector, 2012). Besides, ensuring the educational quality and efficiency as well as universal comprehensive growth of education is also the core of education fairness (Giddens, 2000). Accordingly, we propose a new model and three mechanisms to optimize existing ways.

3. Design OF IRCS&IRSE MODEL

The traditional construction model of DERs based on individual schools fails to bridge digital divide and provide equalization of public educational service (Xiong, Yang, & Zhang, 2013). With the ICTs applied in education, distributed DERs of all the schools in the same region can link. Unfortunately, there still exists barriers in the co-construction of DERs, which leads to fragmented Information Island. We had abandoned the obsolete notion that DERs could only develop by teachers and schools, but had brought in marketization mechanisms, and designed the co-construction configuration model of DERs achieved by a three-way partnership of the government, enterprise and school (Yang, & Yu, 2014, p.113). The government collects and manages the funds which was used to disperse to schools, and plans and purchases the educational resources and services. Enterprises of educational software development focus on instructional design, technical innovation and learning material development. As customers, schools can utilize the resources and give feedback on the quality regarding their contents, presentation styles, usefulness and usability of the learning tools. The model separates purchase, development and utilization, and is supposed to improve the quality of the resources. It is assumed that the model can exert the competitive advantage of three parties: enterprises with high technology and efficiency, the government which has the advantages of funding, supervision and management, and schools which can focus on teaching and learning design as well as feedback. Integrating outsourcing of public service with the idea of "application-driven, government-led and enterprise-develop", the IRCS&IRSE service configuration model was established, as shown in figure 1.

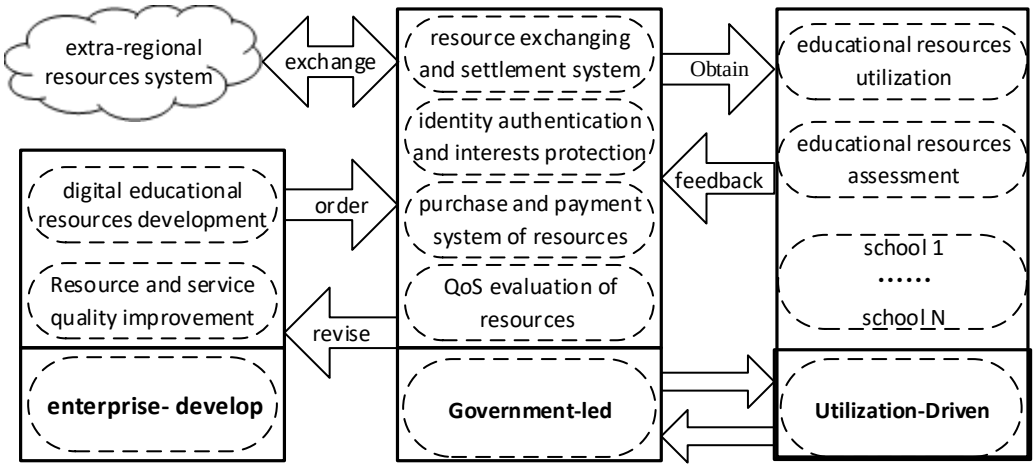

Figure 1. Co-construction and Sharing and Exchanging Model of DERs

Application-driven mechanism means the educational resources should meet users' diverse demands, and users' feedback may decides the resource purchase price. Obviously, in order to maximize benefits, enterprises are forced to improve the quality of educational resources continuously. Government-led means the government actively leads the third party organizations into the supply of DERs by funding, management and supervision. Enterprise-develop refers to

introducing market competition into educational resources supply. Enterprises can produce high quality educational resources and provide personalized service due to their technological and intellectual advantages. Besides, they can also afford quality improvement, technical support and other services. The government is the purchaser of DERs; enterprises who developed DERs take the role of providers; and all the teachers and students act as users of DERs. Traditionally, the government appointed schools to develop DERs, which resulted inadequate and in inferior of the resources that could not satisfy the users. Therefore, the establishment of the demand-oriented education information resource supply system shall conform to the concept of "application-driven, government-led and enterprise-develop".

The aim of DERs configuration is to provide users with equal opportunity to get access to the educational resources. The realization of the aim depends on the performance improvement of every related part in the resource supply system (Swanson, 2007). Performance means the degree of effective output of different levels, including efficiency, the quality of products and services, and the contribution of the institutions (Premchand, 1993). Performance improvement in this paper means utilizing reasonable combination of various resources to achieve the optimization of function and utility. In order to achieve high performance of DERs configuration, several equal public service mechanisms were explored from the perspectives of resource allocation efficiency, service quality and efficiency of IRCS&IRSE model.

4. Capital-shunt mechanism

Against the traditional "comprehensive quota and special subsidy" method, which means that the funding is not only based on the actual number of students and each student's quota standards, but also considering schools' special needs. (Lin, & Chen, 2011). Apparently, this strategy which is influenced by planned economy and equalitarianism, leads to the imbalance between the fee of hardware and software (some schools invest heavily in hardware and environment construction, but lack high quality educational resources, and other schools purchase massive educational resources, but lack matched educational environment), and irrational purchasing (e.g. large numbers of educational resources or hardware and devices, neglecting the quality and utilization of resources) (Yang, Xiong, & Bian, 2013). We put forward the resource construction investment strategies featured by "dynamic capital-shunt", as shown in Figure 2. We simply change the capital distribution strategy to improve efficiency of educational resources funds without changing total amount of investment. Optimal utilization of educational resources is the destination and criterion of resource allocation, which depends on the quality of resources and the information environment. In order to improve the efficiency of educational expenditures, the dynamic balance between software funds and software funds is necessary. In this case, the utilization of educational resources will increase significantly in the long run.

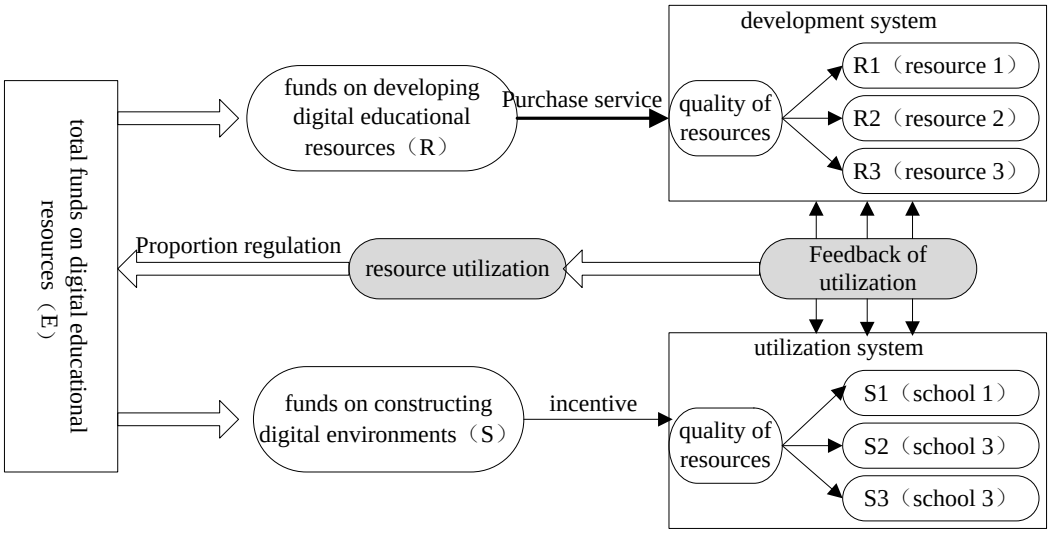

Figure 2. Dynamic Investment Model of DERs

As shown in Figure 2, the construction fund of DERs no longer dispersed to every school, but distributed by the education sectors wholly, and the total budget E is divided into digital resource development funds R and information environment funds S. R will be used to purchase high-quality DERs, and S is mainly used for environment construction. The ratio between S and R will be determined by the actual utilization of each school. The dynamic adjustment of the proportion between two kinds of funds forms positive correlation between resource quality and utilization.

From the perspective of digital educational resource utilization, the information environment construction funds of every school will be determined by its utilization of resources and participation in giving feedback. In order to acquire the higher funds of information environment construction, schools will encourage teachers and students to utilize the resources. Dynamic capital-shunt strategy employs the economic leverage to realize the efficiency of resources configuration. Resource configuration model changed from single school "self-construction" to the "multiple-determine" model of "government purchase, enterprise develop and school utilize". Furthermore, the payment method of government changes from package deal to paying according to users' formative evaluation. Obviously, the static investment strategy is replaced by the dynamic optimal regulation strategy. The transformation ingeniously solves the separation between resource construction and utilization, and the efficiency of resource configuration will greatly improve.

In order to validate the efficiency of the mechanism, a simulation software programed by Vensim is developed to simulate the capital shunt mechanism. As is shown in figure 3, a five-year cycle of education informatization is selected to simulate the variation of the dynamic balance between resource development and environment construction. Aiming at different problems at different stages of education informatization, the optimal result can be acquired by setting different values for correction parameters in Vensim. The simulation demonstrates that investment strategy will vary at different stages of education informatization. At the early stage of education informatization (e.g. 0-24 months), there exists a lack of high-quality resources, and it is necessary to increase the resources development budget. When the quality and quantity of resources reach a certain stage (e.g. 27 months), the utilization of the developed high-quality resources will become the focus of the fund investment. Normally, at the early stage of informatization, while the foundation of the information environment has already deployed, the resource development funds are more likely to be increased. If the region's informatization is under steady development (27-60 months), the ratio of resource development to environment construction will present moderate fluctuations between a certain extent. If the region's informatization has been well developed, the quantity and quality of the resource generally meet the current users' requirements, then the distribution of funds should be inclined to improve the environment to incentivize for resource utilization. In addition, education resources, equipment and platforms should be updated according to the development during a certain time period. Obviously, decision makers only need to adjust education informatization funds by changing the input allocation coefficient. The total investment remains relatively unchanged, but only the structure of funding configuration is to be optimized to obtain the highest investment benefit.

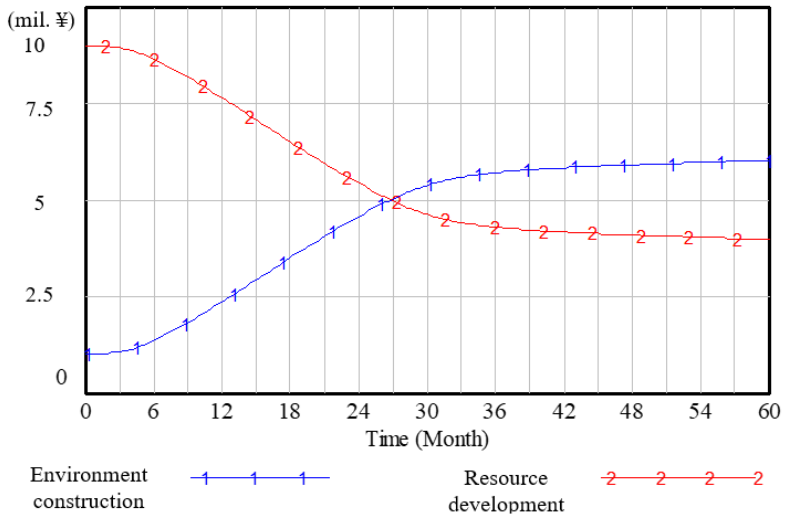

Figure 3. Simulation of the Dynamic Balance between Resource Development and Environment Construction

5. Determining DERs' price by users' feedback

According to Robbins, quality refers to the ability that a product or service can meet the customers' requirements and expectations (Robbins, 2005). Analogized to the quality of DERs, it can be illustrated as the degree to which the DERs can meet the users' requirements and expectations. More specifically, high quality DERs should be developed under the guidance of learning science and theory, considering learners' cognitive styles and knowledge levels, and catering to learners' requirements, with innovative instructional design, logic content organization and favorable presentation. High-quality DERs are those that can be adapted to different learners, environments and social development, and can constantly update to satisfy users' requirements. Traditionally, teachers develop DERs for themselves according to their requirements. In fact, primary and secondary school teachers possess good ability of instructional design, but lack digital art design and multimedia creation skills. It results in low quality of DERs even though huge funds are invested in educational resource development. To eliminate this long-existing problem, the on-demand service has been designed. It means that the government purchases DERs from the educational software enterprises, and the payment depends on users' satisfaction degree which is reflected on DERs' utilization bonus point accumulation (BPA). In this way, the high-quality DERs will be provided to the users in the form of "services" according to service agreements. Therefore, personalized DERs and services is dynamically provided to the users according to their demands. Specifically, educational software enterprises bid to develop DERs, and they must obey market regulations and the rule of "survival of the fittest". The DERs payment is calculated according to the DERs' BPA which will be settled in a certain period according to the whole users' utilization in a certain region, such as clicks, downloads and browsing time, as well as users' grading on DERs. DERs are paid according to the actual utilization BPA in every half year or one year as a settlement cycle, according to the payment measurement model shown in formula (1). Therefore, the enterprises will be forced to develop and revise DERs according to users' dynamic requirements.

$$M = \sum_{i=1}^{k} \frac{F}{\sum_{j=1}^{n} C_j} C_j p_j \qquad (1)$$

Here, M represents the funds that the government paid to a certain educational software enterprise in a settlement cycle. F refers the total budget of the government of a certain region for purchasing DERs. C_j refers the BPA acquired by resource j, and Pj represents the control parameters of purchase price for resource j. n means the total DERs purchased by the educational department, and k refers the total DERs developed by a certain educational software enterprise.

Table 1

Simulation of DERs' BPA and Payment Variation

NO.	Total users	BPA	Payment (CNY)	Coefficient	Actual Payment (CN)
R_1	6539	27008	9812.94	1.0	9812.94
R_2	6381	43186	15690.97	1.2	18829.16
R_3	6051	38256	13899.73	1.2	16679.67
…	…	…	…	…	…
R_{998}	5832	11923	4332.03	0.8	3465.63
R_{999}	6074	39336	14292.13	1.2	17150.55
R_{1000}	5669	43562	15827.58	1.2	18993.1
average BPA：27523			STDEV of BPA：12762		
range of BPA：[5001,49968]			total budget：10 million(CNY)		

The simulation result in Table 1 demonstrates that DERs' BPA ranges from 5001 to 49968 in the settlement cycle T. The total number of DERs is 1000, the government's budget of DERs development is 10 million CNY, and the average BPA of the 1000 DERs is 27523, thus the conversion rate of the BPA is about 0.3633. The BPA is related to the number of users and the quality of DERs, especially the satisfaction of the users. As shown in Table 1, the number of users for R1 is more than that of R2, but the BPA of the former is significantly less than that of the latter. It implies that the quality of R2 outperform that of R1, and the payment will be less accordingly. Figure 4 shows 20 different enterprises' BPAs and payments in a settlement cycle. Obviously, the payment of a DER is proportional to its BPA. For the enterprise, they are paid developing fees by government according to the BPA of all the DERs developed by them. It is assumed that a resource development enterprise entrusted by the government (E1) is responsible for the development of the resources.

The purchase price of each DER can be calculated by multiplying the conversion rate with the acquired BPA. Coefficient is introduced to encourage the enterprise to develop high-quality DERs, which drives the cash to flow towards high-quality DERs although the investments of every DER are the same. Thus, the actual payment of each DER is the product of the BPA, conversion rate and the coefficient. For example, R9, R12 and R20 in figure 4 are required to improve their quality badly.

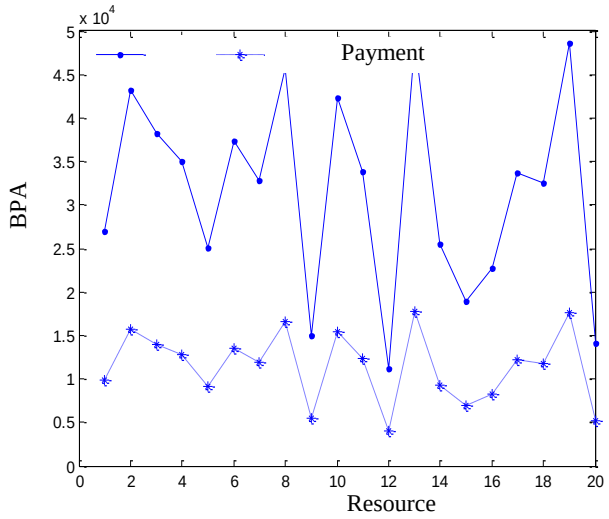

Figure 4. Simulation of DERs' Payment Depending on BPA

6. Determine schools' information environment construction funds by utilization

Schools can share the same high-quality DERs developed by enterprises, and their duty is to make the best use of DERs. The reality is that the DERs pool possesses massive high-quality DERs, but

many of them is idle. Without supervision, users' learning motivation may not be high, which leads to the waste of high quality DERs. Therefore, to achieve education fairness, the utilization of DERs need to improve. According to the idea of capital-shunt mechanism, DERs are developed by the enterprises, but the information environment construction is funded by the government under the schools planning. Therefore, all the users' utilization of the DERs of a certain school decides its information environment construction funds. Each user in a certain region is given an account with a certain amount of educational vouchers according to the uniform standard to access DERs in the common library. Users consume points in the utilization of DERs. Meanwhile, they can get bonus point (BP). And the account can be replenished with points after exhaustion except for those who are not active in utilizing DERs and fail to reach the consumption benchmark. The education authority sums up all the users' BPAs in a certain region and period, and accordingly determines the total information environment construction funds of this region. The conversion rate of the BPA into funds is acquired through dividing total funds by the total BPA in the region. Every school calculates the total BPAs of its users within a settlement cycle, and gets the funds for information environment construction via multiplying its total BPA by the conversion rate. The funds usually are used for information environment construction, training service and user incentive. In order to obtain more information environment construction funds, schools will stimulate their teachers and students to access and utilize DERs according to their own teaching or learning needs. Therefore, the funding distributed from the government to certain school can be defined as formula (2):

$$Q = \sum_{i=1}^{n} C_i \times \left(\frac{p}{\sum_{j=1}^{m} c_j}\right) \qquad (2)$$

Here, Q represents the utilization budget that a school can get in a certain settlement cycle; C represents a single user's total BPA; P represents education authority's total education budget; n represents the number of users in the school; and m represents the total number of users in a region.

In a settlement cycle, the users' utilizations of DERs are different. Accordingly, their BPA will be various, and the distributable information environment construction funds of each school will be different. Traditionally, the appropriation for information environment construction will be distributed according to the number of students in each school. In contrast, the new distribution model distribute fund based on the actual usage of DERs in each school. This model changes from a stereotype way of distribution to a flexible user-centered usage incentive way which in turn arouses the external and internal motivation. Through the analysis of users' motivation of utilizing DERs and the decision-making behaviors, we will explore the factors affecting DERs' usage, improve the recognition and satisfaction of DERs, and ultimately improve the utilization of DERs. The user utilization incentive is the breakthrough point of the mechanism design, and the BPA can dynamically monitor schools' efforts on the improvement of the information environment and the promotion of the DERs utilization. Different incentive strategies based on users' utilization is designed to promote the principle of "more benefits, more utilization". From the schools' perspective, the higher the utilization rate means the more information environment construction funds. Thus their motivation of improving information environment construction will be incentivized which in turn facilitate users to utilize DERs. Apparently, the user's enthusiasm to utilize DERs will increase, and it will form a virtuous cycle regarding the increase of number of users, the improvement of information environment and the effective investment of government funds.

As a kind of electronic virtual currency, BPA of a certain DERs can represent its relative value. The BP can be obtained from the numbers of visits, downloads, and the duration of online learning. The visiting refers to the accessing frequency, and with one visit, the BP will be added once according to the rules. When a resource fulfills the user's requirements, the user tend to download the resource for repeated offline learning, then the DER will get the maximum BP. In a settlement cycle, the BPA of the resources developed by a certain enterprise will be converted to the enterprise's income.

The BPA of a DER can reflect users' satisfaction and utilization of the resource. The BP mechanism is based on users' feedback, and the BPA of the DER decides its purchase price, which brings about the transformation of the concept of DER construction and management. Firstly, by

using economic means to control the quality of resource development and evolution, a new business operation mode of DERs is created. There will be many educational software enterprises involving in the education resource development. Thus, the cooperation among enterprises, universities and research institutes will be promoted. Secondly, the quality of resources is ensured at the development stage by transforming from school self-construction to unified purchase of DERs by the government. The government entrusts teachers and experts to fully study the types of DERs and develop construction schemes. Meanwhile the government makes qualified software enterprises to bid for the development of high-quality DERs. Thirdly, it promotes the evolution of DERs. It stimulates enterprises to increase the quality of the resources continuously to obtain a higher purchase price of DERs according to users' feedback. According to the payment protocols, the purchase of DERs is not a package deal. It means DERs are not one-time products, but continuously evolve and generate multiple upgraded versions according to the users' feedback.

According to the above incentive mechanism, the government is supposed to issue each user 400 educational vouchers (equal to 400 CNY) and define that each user can obtain one BP after consuming one educational voucher. As is shown in Table 2, the total number of users at school S1 is 1838, and it can obtain 735,200 vouchers in advance. However, the funds a school can get are not related to the initial vouchers, and what really matters is only the consumption of the vouchers and acquisition of the BPA. For example, the initial vouchers of S2 is 675,800, and it only obtains 180,800 BP in the settlement cycle. In contrast, the initial vouchers of S259 is 421,600 CNY, and it obtains 693,000 BP in the same settlement cycle. It implies that the users of S259 utilized DERs far more frequently than that of S2.

The conversion rate of BPA refers to the funds per BP, and it varies with the government's budget for DERs and the total BPA of the region in each settlement cycle. In condition that DERs' utilization funds of the region remain unchanged, the greater the total BPA is, the smaller the conversion rate is, which indicates a higher utilization rate of DERs in this region.

As aforementioned, the actual funds of certain school is no longer directly related to the number of students in this school, instead, is determined by the product of the BPA and the conversion of that region. As we can see in table 2, the school's actual incentive funds in a settlement cycle can be calculated by multiplying the total BPA of the school and the conversion rate.

Table 2

Simulation of schools' BPA and its IECFs

School	Numbers of users	Voucher (CNY)	BPA (points)	Conversion rate	get funds (CNY)
S1	1838	735,200	4027,900	0.06	421,600
S2	1692	675,800	180,800	0.06	10,800
S3	1981	792,400	3067,400	0.06	184,100
…	…	…	…	…	…
S257	1457	582,800	117,400	0.06	7,000
S258	968	387,200	2115,400	0.06	126,900
S259	1054	421,600	693,000	0.06	41,500

Figure 5 demonstrates that the funds of the schools according to traditional distribution strategy are proportional to their total students at school, while the actual incentive funds are irrelevant to that. Since the number of students in S3 is close to that of S4, and their incentive funds may also be of little difference according to the traditional distribution strategy. However, under the incentive mechanism, the actual incentive funds of S3 is 140000 CNY, and that of S4 is 106400 CNY, which is about 40000 CNY less than S3. It indicates that the population of the two schools is almost the same, but their different BPAs lead to different amounts of incentive funds. Assuming that other conditions remain unchanged, in a certain period, the more frequent the users in a school utilize DERs, the larger BPA the school gets, which indicates that the school's education informatization level is higher. In the settlement cycle, the fact that the BPA of S3 is more than that of S4 can partly reflect that the users' motivation to utilize DERs and the education informatization level of S3 is higher than that of S4. In order to get more incentive funds, S4 needs to adopt appropriate incentives, such as enhancing the network environment, improving the information literacy of all the teachers and students, motivating users to use DERs actively. The comparison

between the two strategies is shown in Figure 5.

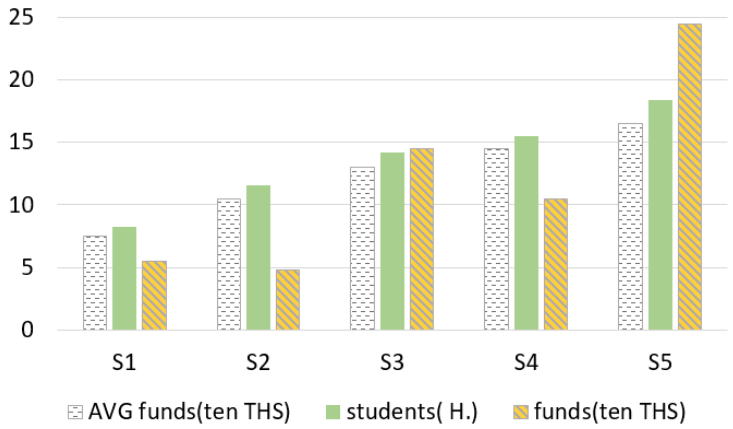

Figure 5. Simulation of Schools' IECFs Depends on Their Use of DERs

7. Conclusion

The IRCS&IRSE model is conducive to high-quality resource development and resource utilization. In order to reach the goal of the model, three mechanisms are introduced. The core is the capital-shunt mechanism, which means dynamically regulating the expenditure ratio of DERs' development to environment construction to improve the resource distribution efficiency. In essence, the capital-shunt strategy just divides the capital into two parts, one is used as the development fees of DERs and motivation to stimulate enterprises to improve their resource quality, the other is used as IECFs and encouragement to stimulate schools to strengthen the utilization of DERs. Consequently, DERs' purchase prices are determined by users' feedback, which may help improve the quality of DERs. In order to acquire higher development fees of DERs, enterprises may take brains to polish the content and presentation of DERs, thus improve the quality of the resources DERs. And the other mechanism is determining schools' information environment construction funds by their use of DERs. In order to obtain higher information environment construction funds, schools may strive hard to stimulate and encourage their teachers and students to utilize DERs, and improve the utilization of DERs.

In this paper, we propose the IRCS&IRSE model and introduce public service outsourcing notion into the optimal configuration of DERs, exploring the "government purchase, enterprise develop and school utilize" resource service system. The capital-shunt strategy needs not increase the total investment but just regulates the proportion of the funds for DERs development and education informatization, and promotes utilization efficiency of these funds. Determination of the purchase price of DERs by user feedback not only eliminates defect of emphasizing development while neglecting utilization of resources, but also ensures high quality of DERs from the initial stage of development and promotes the quality of DERs in the process of utilization. The school's BPA is an important reference for the distribution of information environment construction funds, which prompts the schools to improve education information environment, encourages the teachers and students to actively use high-quality DERs and promotes DERs utilization. Simulations and findings show that the mechanisms work well and achieve the desired results.

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