Analysis of the Development Prospect of Basic Education of Informatics in Xuzhou Based on SCIR Double-Layer Coupling Network

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Abstract. In the context of the "Double Reduction" policy, a questionnaire survey was conducted on the current development of basic informatics education in Xuzhou City, and the survey data were statistically analyzed to summarize the problems encountered in informatics education. And based on the SCIR model to construct a two-layer coupling network, we simulated the changes of the number of students participating in online and offline training of informatics in Xuzhou city, and through modeling simulation, we concluded that the number of people participating in online education will surpass the number of traditional education in the post-epidemic era, while the government's guidance can effectively promote the development of informatics education. Finally, the simulation results are used to analyze the development prospect of informatics education, which is important for the development of basic informatics education in Xuzhou.

Keywords: Informatics · Regional Basic Education · *SCIR* Model · Two-level Coupling Network

1 Introduction

The Ministry of Education on the issuance of "Compulsory Education Information Technology Curriculum Standards (2022 Edition)" [1] points out that information technology is an important part of the modern science and technology field, and the curriculum focuses on cultivating information awareness, computational thinking, digital learning and innovation, and information social responsibility, which together promote the improvement of students' digital literacy and skills. Compared to other disciplines, the content of informatics teaching is constantly adjusted with the rapid changes in information technology, and the lack of rich teaching experience in related courses makes the popularization of high-quality informatics education challenging. The implementation of the "double reduction" policy in 2021 will break the old pattern of the education industry and bring new opportunities and challenges to the development of basic informatics education.

C. F. Peng et al. (Eds.): EIMT 2023, AHSSEH 8, pp. 1209–1218, 2023.
https://doi.org/10.2991/978-94-6463-192-0_156

Table 1. Survey results

Current Student Survey Project	Survey Results	Student Parent Survey Project	Survey Results
Participation in Informatics Training	9.56%	Informatics education is completely beneficial	15.39%
Not interested in informatics	27.96%	Informatics education can conflict with traditional curriculum	30.48%
Lack of understanding of informatics	22.97%	No good conditions for informatics education	36.89%
Teaching quality does not meet expectations	17.4%	Informatics education is completely unhelpful	17.24%
Parents oppose informatics education	22.11%		

2 Status of Development of Basic Education of Informatics in Xuzhou

In November 2021, a questionnaire survey was conducted on students and parents in primary and secondary schools affiliated with in five urban areas, three counties and two county-level cities in Xuzhou City. 1,674 questionnaires were distributed, with 1,403 valid questionnaires, which passed the reliability and validity tests. The survey data as shown in Table 1.

After investigation, the following problems in the development of basic education of informatics in Xuzhou were found: students lack subjective awareness and insufficient motivation to learn; parents are backward in education and insist on the supremacy of marks; school teachers are weak and the curriculum lacks diversified development; there are still problems in the development of informatics and the development breakthrough urgently needs government assistance.

3 Information Dissemination Model Based on SCIR Double-Layer Coupled Network

3.1 Construction of *SCIR-Based* Double-Layer Coupling Network

In 1927, Kermack and McKendrick proposed a classical model of infectious disease dynamics, the SIR model, which showed that the virus propagation mechanism was very similar to the information propagation mechanism in social networks, and scholars have conducted in-depth studies on this since then. Zanette D H used the SIR model The propagation of information in small-world networks was studied [2]. Moreno Y proposed a scale-free network opinion propagation model based on the SIR model [3]. Xiong et al. constructed a SCIR model by adding contact states to describe the propagation of public opinion on online microblogs [4], which laid the foundation for further research on information propagation in social networks.

With the development of technology, there are two mainstream teaching methods: traditional education and online education. Traditional education is delivered face-to-face and students are in the offline network; online education is delivered online and students are in the online network. In this paper, we construct a two-layer coupled network [5] topology based on the SCIR model [6] and add a perturbation term to the model γ to simulate the impact of government guidance on the development trend of informatics education.

With the help of SCIR information dissemination model, this paper classifies Xuzhou students at all stages into five states and gives the following definitions.

Unknown state (S state): students who do not know about informatics training.

Known state (C state): knowledgeable about informatics education, but hesitant to participate in training.

Offline participation state (I1 state): having knowledge of informatics education and recognizing the level of local informatics training and participating in local offline training.

Online participation state (I2 state): having knowledge of informatics education, not recognizing the level of local informatics training and attending online training in other regions.

Immune state (R state): Students who have knowledge of informatics education and decide not to attend informatics training.

Students who are in the network have different probabilities of nodal transformation, as shown in Fig. 1. Students in the state S will transform to the state C with probability μ. Since there are regional differences in the development of informatics education, students in state C with probability δ_1 choose to enroll locally and are transformed into state I_1, while some students with probability I_2 choose online training in other regions and are transformed into state δ_2. If students in the state C do not participate in informatics training with probability θ, they transform to the state R. When affected by the epidemic, students who participate in offline training will shift to online training. Therefore, the student status transfer is shown in Fig. 2.

When region m is affected by an epidemic, offline training in this region will be online training, when there is no offline training in the region, and the probability of this

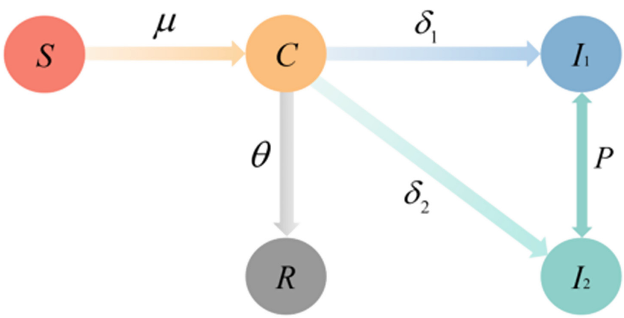

Fig. 1. Schematic diagram of state transfer

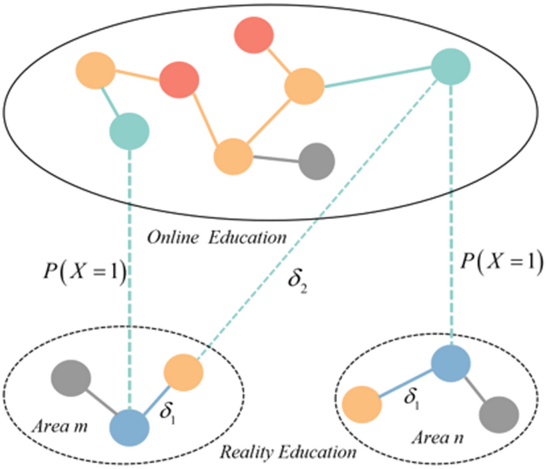

Fig. 2. Schematic diagram of state transfer in different regions

situation is related to the probability of the epidemic occurring in the region.

$$X_m = \begin{cases} 0, & \text{if there is no outbreak in the region} \\ 1, & \text{if there is an outbreak in the region} \end{cases} \tag{1}$$

Whether students receive informatics education in region m also depends on the quality of education in that location, and this paper chooses the teacher-student ratio as a proxy measure of education quality, which indicates the average educational resources received per student. The teacher-student ratio is positively related to the quality of teaching and learning. n_t enotes the number of teachers in a school and n_s denotes the number of students trained, then the teacher-student ratio R_{st} can be expressed as

$$R_{ts} = n_t / n_s \tag{2}$$

The teacher-student ratios of different regions in Xuzhou are normalized and mapped onto the interval [0, 1] to get the education quality of each region. When Q is closer to 0, it means that the education quality of the place is worse; when Q is closer to 1, it means that the education quality of the place is more excellent.

$$Q_m = \frac{R_{st-m} - R_{st-\min}}{R_{st-\max} - R_{st-\min}} \tag{3}$$

In a two-layer network, the nodes between layers are coupled, which is reflected in the network topology by the three inter-layer connection patterns of homogeneous, heterogeneous and random connections. In this paper, the matching coefficient is introduced to quantify.

$$\rho = \frac{\sum_{K_x K_y} K_x K_y (e_{K_x K_y} - a_{K_x} b_{K_y})}{\sigma_{K_x} \sigma_{K_y}} \tag{4}$$

where $e_{K_xK_y}$ denotes the proportion of all edges of the network with connectivity K_x and K_y, a_{Kx}, b_{Kx} denotes the proportion of edges with degree K_x, K_y, and σ_{K_x} denotes the variance of the random variable K_x.

In this paper, we combine K-Shell [7] and internal and external trust to represent the trust of node i in a two-layer coupled network, denoted as the composite metric KSCC.

$$KSCC(i) = \alpha\left[tr_{i-in}\right] + \beta\rho\left[tr_{i-out}\right] \tag{5}$$

where ρ denotes the degree correlation between the online network and the offline network, α and β are the local and global impact factors, respectively, and satisfy $\alpha+\beta = 1$.

Government guidance affects the developmental dynamics of informatics education, and in this paper, we set γ to represent the positive government influence on informatics education. Then, the degree of students' knowledge about informatics education in the two-layer coupled network is represented by the government guidance γ and the nodal trust degree KSCC, i.e., the probability of students' transfer from S-state to C-state.

$$\mu'(t) = \left[\gamma + KSCC(i)\right]e^{-t} \tag{6}$$

Denote the proportion of students in each state at moment t as $S(t)$, $C(t)$, $I_1(t)$, $I_2(t)$ and $R(t)$. Assuming that the total number of students remains constant over time, the relationship between the nodes can be expressed as

$$S(t) + C(t) + I_1(t) + I_2(t) + R(t) = 1 \tag{7}$$

Students in S-state are transformed to C-state with probability μ and the amount of change of S-state per unit time Δt is $-\mu S(t)\Delta t$, and these students learn about informatics education through the neighboring nodes. When the government promotes informatics education, the state transformation of students who originally transformed from S-state to C-state remains unchanged, while other students in S-state will $\gamma(1-\mu)S(t)\Delta t$ learn about informatics education and transform to C-state because the government promotes it with γ force. Then the number of changes in the proportion of students in the S state can be expressed as

$$S(t+\Delta t) - S(t) = -\left[\mu + \gamma(1-\mu)\right]S(t)\Delta t \tag{8}$$

For the C state, there are $\left[\mu + \gamma(1-\mu)\right]S(t)\Delta t$ students who are transformed from the S state. When the government did not intervene, the students in state C were converted to state I_1, I_2, and with the probability of $R\delta_1$, δ_2, and θ, respectively, and the change in the proportion of students in state C during the time of Δt was $-(\delta_1 + \delta_2 + \theta)C(t)\Delta t$. When the government promotes informatics education, the number of students who are still in the C state is $[(1-\delta_1) + (1-\delta_2) + (1-\theta)]C(t)\Delta t$, and they are also transformed to the I_1, and I_2 R states through the government's guidance, and the change in the proportion of students in the C state in the time of is $\Delta t\gamma[3 - (\delta_1 + \delta_2 + \theta)]C(t)\Delta t$. Then the number of changes in the proportion of students in state C can be expressed as

$$C(t+\Delta t)-C(t)=\left[\mu+\gamma(1-\mu)\right]S(t)\Delta t-(\delta_1+\delta_2+\theta)C(t)\Delta t \\ -\gamma[3-(\delta_1+\delta_2+\theta)]C(t)\Delta t \tag{9}$$

The amount of change in the student ratio of other states is similar to that of S and C, and the kinetic differential equation of the SCIR double-layer coupled network is obtained by differentiating Δt.

$$\begin{cases} \frac{dS(t)}{dt}=-\left[\mu+\gamma(1-\mu)\right]S \\ \frac{dC(t)}{dt}=\left[\mu+\gamma(1-\mu)\right]S-\{(\delta_1+\delta_2+\theta)+\gamma[3-(\delta_1+\delta_2+\theta)]\}C \\ \frac{dI_1(t)}{dt}=\left[\delta_1+\gamma(1-\delta_1)\right]C-X\left[\delta_1+\gamma(1-\delta_1)\right]C \\ \frac{dI_2(t)}{dt}=\left[\delta_2+\gamma(1-\delta_2)\right]C+X\left[\delta_1+\gamma(1-\delta_1)\right]C \\ \frac{dR(t)}{dt}=\left[\theta+\gamma(1-\theta)\right]C \end{cases} \tag{10}$$

3.2 Simulation of *SCIR* Double-Layer Coupling Network

In this paper, we use Python to simulate the SCIR double-layer coupling network to explore the state of informatics training in different regions of Xuzhou City, the changes brought by the epidemic to students' learning styles, and simulate the influence of government guidance on informatics education in Xuzhou City by adjusting the value of γ. Xuzhou city was divided into 5 urban areas, 3 counties and 2 county-level cities according to administrative regions, and numbered them separately to obtain the set of regional divisions of Xuzhou city $D=\{a,b,c,d,\cdots,i,j\}$. Based on the information, the teacher-student ratio and the probability of epidemic in each district and county were obtained as shown in Fig. 3.

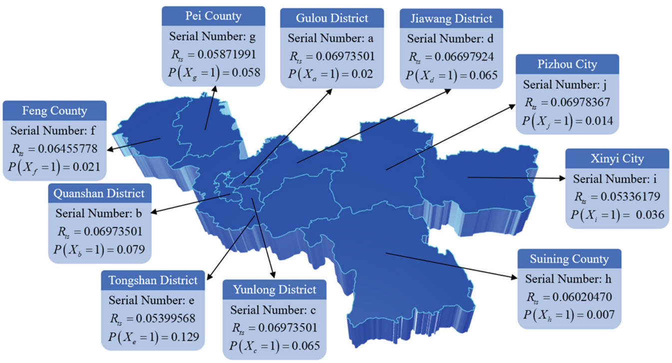

Fig. 3. Teacher-to-student ratio and probability of epidemic in Xuzhou city by district and county

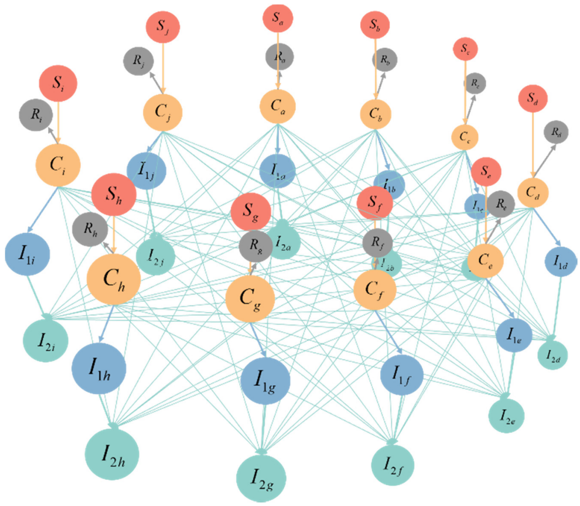

Fig. 4. Schematic diagram of Xuzhou SCIR double-layer coupling network

The SCIR double-layer coupling network was applied to 10 regions in Xuzhou City to obtain the state transfer of student nodes in each region, as shown in Fig. 4, where S_a denotes students in region a in S-state, where S_b denotes students in region b in S-state, etc.

The transfer probability of each node is calculated by the proportion of students and the teacher-student ratio in each region of Xuzhou city; reference [8], set the internal influence factor $\alpha = 0.5$ and the external influence factor $\beta = 0.5$; input the parameters into the model. When Xuzhou informatics training is not influenced by the government, the simulation results of SCIR double-layer coupled network are shown in Fig. 5. When $t > 8$, the proportion of students in the R node tends to be stable, indicating that about 11% of students will participate in offline informatics training and 15% will participate in online informatics training as time progresses without the government promoting informatics education. The epidemic has resulted in more people participating in online training than in offline training, so informatics training institutions need to improve their online teaching strength and improve their teaching assistant services.

When γ takes values of 0.1, 0.3, and 0.5, respectively, and other parameters are kept consistent, the evolution of I with t for different governmental steering power as shown in Fig. 6. As the value taken by γ increases, i.e., the positive influence of the government on informatics education strengthens, the value of R gradually increases, i.e., the number of students participating in informatics training is increasing. When $t > 6$, the proportion of students in the R node tends to be stable, indicating that the government can promote students' participation in informatics training through guidance; and as the government's guidance increases, the peak proportion of students participating in informatics training increases, and when $\gamma = 0.5$, 60% of students will participate in informatics training in the future.

By constructing a two-layer information dissemination topology and using the SCIR model to simulate the choice of informatics training by students in each region of Xuzhou,

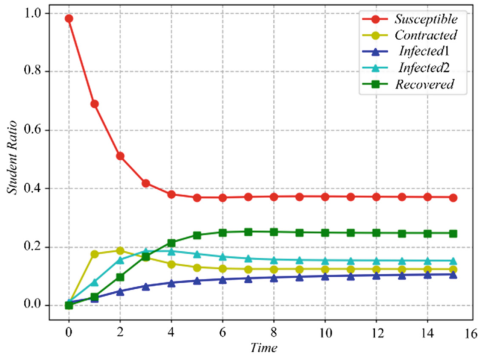

Fig. 5. Simulation results of *SCIR* double-layer coupling network

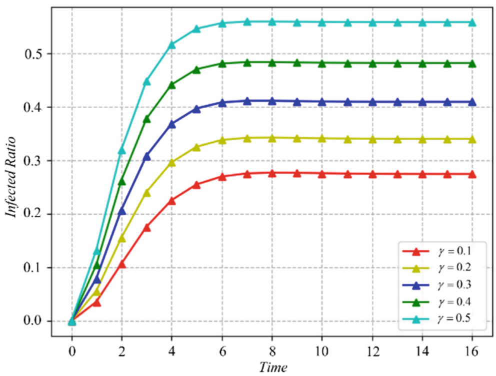

Fig. 6. Simulation results for different impact strengths

we were able to effectively explore the development of informatics education in Xuzhou; and by changing the strength of government influence for simulation, we found that government guidance can promote the development of informatics education in Xuzhou. The model is more contemporary compared with the traditional information dissemination model, which is in line with the characteristics of information dissemination in the post-epidemic era, and the research results are more relevant to the actual situation.

4 Conclusion

Currently, informatics education is hampered by students' and parents' perceptions as well as schools' hardware levels, with only 9.56% of students receiving informatics education, and the informatics training market is still in its preliminary stage. With the development of information science, information technology is widely used in life, more and more parents and students realize the importance of informatics education, more students will participate in informatics training, and there is huge room for the growth of informatics education in the future.

With the release of the "double reduction" policy, the informatics training market is growing rapidly, but from the perspectives of teaching quality, faculty strength and hardware level, the development of informatics training institutions is mixed, and there is still a lot of room for improvement in the future. In the post-epidemic era, the importance of online education will surpass that of traditional education, and training institutions should seize the opportunity of the times to enhance online teaching strength and improve the service level of teaching assistants. According to the SCIR double-layer coupnling network constructed in this paper, the government will improve the development of basic informatics education in Xuzhou by increasing supervision, regulating the market, and actively promoting informatics education, and about 60% of students will receive informatics education in the future.

Acknowledgment. This project is the result of the innovation and entrepreneurship training program for college students in Jiangsu Province (Project Number: 202211998102Y).

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