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A Complex Dynamic Systems Perspective on Secondary School Information Technology Teachers' Learning

Linlin Wang[1], Tiwei Tao[2*],Mingxia Liu[2], Zhenhuan Kang[1],Yifei Sun[3]

School of Mathematics and Statistics, Taishan University, *Tai'an*, China [1]

School of Information Science and Technology, Taishan University, Tai'an, China [2]

Middle School of Taishan college, Tai'an, China [3]

***Abstract*—In recent years, secondary school information technology (IT) teachers' learning has become an emerging field of research, emphasizing that learning is a lifelong developing process. This perspective highlights secondary school IT teachers as learners, emphasizing their subjective initiative. This study runs through the design, implementation and evaluation of teacher professional development projects, applying complex dynamic systems theory to the professional learning process of secondary school IT teachers in China for the first time. It provides inspiration for expert teacher researchers and front-line secondary school IT teachers' professional development, and offers policy suggestions for relevant education authorities and teacher development institutions. It will also contribute to theoretical and practical innovations in domestic IT teachers' learning and professional development.**

***Index Terms*—Information technology,Complex Dynamic Systems, Professional development.**

I. Introduction

With the advancement of Education Informatization 2.0, the transformation empowered by information technology is profoundly impacting educational development. The new round of curriculum reform has fully upgraded students' information literacy. The surging demand for information technology talents in the information society... All these cannot be achieved without the participation of information technology teachers. Building a strong team of information technology teachers is the strategic resource for the development of school informatization. However, the current education still cannot meet the needs of China's economic development. Fundamentally, it has not yet gotten rid of the outdated educational concepts, unbalanced regional educational development, and shortage of innovative talents. Information technology teachers play an important role in science and technology innovation education. Therefore, establishing a high-level team of information technology teachers is the requirement of the times and an urgent issue that needs to be addressed[1].

In the field of education, teacher learning has always been a topic of great concern. As time goes by and epistemology evolves, teacher learning research has also undergone significant changes. In the past thirty years, information technology education research has gradually shifted from the traditional paradigm of positivism and empiricism to the paradigms of relativism and interpretivism[2][3]. This change has led more researchers to get close to the scene and observe the practical context of teacher education in depth, and devote themselves to fully depicting and explaining the real situation of teacher learning. Therefore, it is imperative to conduct teacher learning research on information technology teachers[4]-[6]. At the same time, the rise of complex dynamic systems theory has also brought new perspectives and methods to teacher learning research. This theory rejects the mechanistic and reductionist views of science, emphasizing ecological and holistic perspectives, and regards teacher learning as a complex system's dynamic evolutionary phenomenon. Therefore, from the perspective of teacher learning, complex dynamic systems theory provides a unique theoretical framework to better understand and explain the complexity and dynamics of teacher learning.

This paper will thoroughly study the holistic, dynamic process and contextual characteristics of teacher learning, discuss the paradigm shift in information technology teacher education research, and the application of complex dynamic systems theory in teacher learning. Through this research, we will better understand the nature of teacher learning and provide beneficial insights and directions for future educational research.

Therefore, taking a middle school in a certain area as the background and its information technology teachers as the research subjects, this study aims to thoroughly explore secondary school information technology teachers' learning process and its complexity. Similar to foreign language education, secondary school information technology teachers also need to constantly adapt to the rapid development of science and technology, updating teaching materials and teaching methods. This research will help to better understand the nature of secondary school information technology teachers' learning and provide valuable insights and directions for future educational research. Also, by gaining an in-depth understanding of the complexity of secondary school information technology teachers' learning, it can better support their teaching work in the field of information technology.

II. Background and Importance

In recent years, the theories of secondary school information technology teachers' learning research have also shown a diversified trend, influenced by different educational

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theories. These include behaviorism, cognitive constructivism and sociocultural theory.secondary school information technology teacher learning research pays more attention to the diversity of learning, focusing on developing teachers' skills, knowledge and identity construction to better meet the needs of modern education. In 2018, Kiss examined the learning of five teachers participating in a certain teacher education course, based on the analysis of the teachers' reflective logs. The study found that the five teachers all reflected on the course contents by associating them with their past, present and future events, characters and places, which were highly personalized thinking activities and associations. Based on these, teachers chose course contents they resonated with and formed personal understandings. Therefore, facing the same teacher education course, different teachers learned different contents, and what each teacher actually learned was unpredictable, reflecting the complexity of teachers' cognition and thinking activities. In light of this conclusion, this study called for teacher training courses to pay attention to the nonlinear thinking activities of teachers and create conditions that allow spontaneous teacher learning.Eryok have explored the immediate fluctuations in language reflection and cognition within the context of teachers' pedagogical practices from a nuanced and dynamic perspective, thus underlining the fluid and intricate nature of teachers' reflective processes. Scholars like McQuitty and Mooer, internationally recognized, pay particular attention to the methods through which teachers acquire pedagogical skills, their engagement in professional development activities, and approach these topics through the lens of complex dynamic systems theory. Furthermore, a substantial body of research is dedicated to the dynamic and complex traits of teacher motivation, emotion, and identity [7], probing into the multifaceted and dynamic properties of teacher cognition and learning from diverse viewpoints.

Research on information technology (IT) teacher learning from the perspective of complex dynamic systems theory focuses on the intricate and dynamic characteristics of teacher cognition and psychology, including the interplay between teacher cognition and practice, reflection, motivation, and identity. This approach emphasizes a holistic examination of teachers as individuals within their environments and highlights the social context of teacher learning as well as the interaction between the individual and the environment. It takes into full account the nonlinearity of teacher learning and the variability of outcomes, offering new perspectives and insights for research in IT teacher education.

The significance of this study is that it can provide inspiration for the professional development of expert teacher-researchers and front-line secondary school IT teachers, and provide new evidence and insights for the design, implementation and evaluation of teacher professional development projects. It can also offer policy suggestions to relevant education authorities and teacher development institutions. Specifically, it involves two aspects:

First, in the critical period of national development and reform, curriculum reform and reforms have become the norm, and information technology is constantly updated and iterated. Information technology teachers and researchers need to learn continuously for life-long learning, and constantly improve their professional skills and teaching and research standards[8]-[11].

Second, in the process of continuous expansion of the scale of national teacher training, the design, implementation and evaluation of teacher training projects need more empirical research support. The researcher plans to delve deeply into the real context of a secondary school IT teacher professional development project, and track, record and interview throughout the implementation process of the project, in order to provide inspiration and suggestions for the design, implementation and evaluation of in-service secondary school IT teacher training projects. [13] examined the development and refinement of possible mathematical models for the intellectual system of career guidance. Mathematical modeling of knowledge expression in the career guidance system, Combined method of eliminating uncertainties, Chris-Naylor method in the expert information system of career guidance, Shortliff and Buchanan model in the expert information system of career guidance and DempsterSchafer in the expert information system of career guidance method has been studied. [14] discussed that according to the observations in this paper, an existing mathematical model of banking capital dynamics should be tweaked. First-order ordinary differential equations with a "predator-pray" structure make up the model, and the indicators are competitive. Numerical realisations of the model are required to account for three distinct sets of initial parameter values.

III. Research Design

This project adopts a longitudinal case study method, aiming to delve deeply into the professional development trajectory of a secondary school IT teacher to obtain an outline of her development, establish the key time points and activity events in her development, and rely on the improvement learning in normal universities to understand the complex dynamic system mechanisms of teacher learning.

A. Research Subjects

The subject of this study is a female junior high school IT teacher, Xiaofeng (pseudonym). Xiaofeng is from an urban district in an eastern city, with 6 years of teaching experience. In addition to completing daily teaching tasks, she rarely participates in research projects, paper writing and other research activities.

B. Data Collection and Analysis Methods

The case time span of the study is one semester. The main data collection methods include multiple interviews, classroom observation and collection of related materials.

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This research draws on complex system theory to view the teacher's learning process as a complex system, paying special attention to the various changes of this system in the socio-cultural environment. At the data analysis stage, we focused on examining the critical events that occurred during the teaching transformation, which reflected the teacher's important teaching concepts and stimulated new teaching practices[12]. After multiple readings of the data, we selected three key events for in-depth analysis, including the teacher's motivation to become an IT teacher, the teacher's learning experience during the transformation process, and the teaching challenges faced after the transformation. We took these key events as clues to focus on studying their unique dynamic effects on the case teacher's professional learning and process. Therefore, the entire data analysis process has both top-down and bottom-up characteristics. First, we screened out the data related to these three key events, then used content analysis methods to analyze these textual data, and presented themes through multi-layered coding. Finally, we compared the similarities and differences of themes in the three cases to find commonalities and differences in the teacher learning process.

C. *Research Results*

Before and during the initial stage of the project, from Xiaofeng's current teaching situation, the initial state of the teacher's cognitive system can be described as "equilibrium", that is, the overall system is in a relatively balanced state during the interaction of system elements. Information technology is just a compulsory course rather than a subject tested in high school and college entrance examinations, its academic status is relatively low, class hours are less, and students' attention is low. As a result, information technology teachers are at a disadvantage in performance appraisal and professional development. Before starting the research, Xiaofeng expressed that she loves teaching, "wholeheartedly for the students". But due to the non-core course, she often undertakes some administrative work in the school. When encountering teaching problems, she often dealt with them based on her own experience instead of analyzing and solving problems through research methods. Therefore, her motivation for research activities was not strong at the initial stage. At the same time, during the start of training, due to her major in communication engineering, she had just started contacting information technology related courses after work, so her acceptance was relatively poor initially.

Under this state, the teacher's cognitive system made subtle adjustments, but no significant conflicts or strong fluctuations occurred. After about 5 years, Xiaofeng gradually reached a good state of teaching information technology, with smooth thinking in information technology teaching, and ability to independently solve practical problems through practice and reflection, without significant teaching puzzles and difficulties. In recent years, with the continuous emphasis on computational thinking and the rapid development of artificial intelligence, higher skill requirements have been imposed on secondary school information technology teachers.

"I pay special attention to information competitions. I have guided students to win 2 provincial first prizes and municipal special prizes. In the process of guiding them, I also experienced the interestingness of programming myself, and carried out teaching activities based on the enlightenment of competitions. These have all become my capital, an increasing number of parents seek my consultation and guidance when there are relevant competitions."

In recent years, Xiaofeng's teaching philosophy, thinking and corresponding practices have been continuously supported by students, recognized by parents, and praised by colleagues, which helps Xiaofeng maintain her current teaching philosophy and thinking, and does not tend to change much.

"In my daily teaching, it is easy for a two-level difference phenomenon to occur. Students who are interested in programming are especially active in class, while those who are not interested become particularly evasive after programming frustration. For this situation, I usually teach students in accordance of their aptitude, using some analogical learning methods to stimulate their interest, such as a girl who really likes anime, but easily makes mistakes in programming. I wrote anime-style code in Python to show her, let her see that the originally dull code can be so agile, which immediately ignited her enthusiasm for learning."

At the school level, Xiaofeng's institution is a key school in the city, characterized by a relatively open and democratic school culture. Xiaofeng describes the leadership at her school as providing a "relaxed environment" and "material support":

"The school has given me a very good relaxed environment. Our school's leaders are quite enlightened. They never suppress my ideas and methods; on the contrary, they offer a lot of support. For example, when I organize students to participate in information-related competitions, the school has been covering the registration fees for my students over the years, and they hold meetings to commend students who win awards. Additionally, they have established a competition corner where students don't need to purchase relevant textbooks themselves. This also makes it easier for me to carry out the organizational work for competitions. So, I feel that they have provided me with a relaxed environment and material support."

It is evident that Xiaofeng's pedagogical approach, which is centered around competition-driven inspirational teaching, has garnered the endorsement of her students, yielded commendable academic outcomes, and secured unanimous commendation from both parents and colleagues. Institutional backing at the school level further fortifies this support framework. In light of such affirmation, Xiaofeng manifests a heightened sense of self-efficacy and robust professional confidence. This endorsement reinforces her conviction in the validity and efficacy of her

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competition-oriented instructional philosophy, thereby solidifying her predisposition towards sustaining her current pedagogical orientation rather than pursuing transformative or innovative pedagogical strategies.

Judging from the current situation, the teacher's cognitive system is in a relatively stable state, that is, there are fewer contradictions or fluctuations within the system, and the system tends to maintain its current state. In other words, classroom teaching activities are going smoothly, student needs are met and perform well, and teachers have a strong sense of self-efficacy and professional self-confidence. Soon after entering the project, Xiaofeng entered the research topic selection stage. Xiaofeng participated in course learning, observed evaluation lectures, participated in the final summary meeting, independent theoretical study and expert dialogues and other activities, reviewed her competition-oriented inspirational teaching practice, and discovered problems existing in her current practice. In this process, the teacher's cognitive system was disturbed. The disturbing events included experts conveying different perspectives, supervisor feedback challenging inherent thinking; when the disturbance occurred, the teacher's cognitive system responded, and the system underwent self-organization and emerged new features, teacher learning occurred.

IV. Disturbing Event: Exchange of Expert Opinions

At the beginning of the project, Xiaofeng's competition-oriented inspirational teaching philosophy focused on content teaching and relatively neglected practical teaching, with emphasis on traditional programming examples and simple inspirational teaching, with the addition of competition questions, expanded programming questions and other diverse materials. The main tasks of teachers were to interpret program codes, explain basic knowledge, and do some guiding work and programming training.Soon after entering the project, Xiaofeng noticed that the experts in the training seemed to be conveying views that were slightly different from her previous cognition: while paying attention to code interpretation, they also focused on situational teaching of programming languages. In practical teaching links, project-based training is added to enhance students' participation and hands-on ability, increasing the proportion of the "hands-on" part to make students willing to participate. The whole project becomes a small group teaching, adopting Montessori education methods, mixing students with different levels in groups, ensuring the allocation ratio is 1:2, so that students with good fundamentals have a sense of accomplishment, and those with poor fundamentals have a sense of companionship.

The expert’s evaluation of the class provided Xiaofeng with new concepts and ideas, which entered the teacher’s system as new energy, possibly triggering interactions among the elements of the cognitive system and adjustments to the system. Thus, when a perturbation event occurs, the teacher’s cognitive system responds, interactions occur between the elements inside and outside the system, and some new features emerge locally in the teacher’s cognitive system, indicating that teacher learning is taking place. Specifically, Xiaofeng became aware of problems in teaching practice and gained a deeper understanding of practical problems through processes such as literature learning. Xiaofeng compared the expert’s views on the class with past activities she had experienced and views she had heard, noticed differences in views, and noticed content she might not have paid attention to in the past, indicating that external activities triggered interactions within the teacher’s cognitive system. Since this discovery, Xiaofeng has begun to pay more and more attention to more mentors around her mentioning views that Xiaofeng had previously ignored: paying attention to the extensibility of programming languages. Xiaofeng noticed that another mentor of the project, Professor Liu, also proposed that programming teaching should pay attention to situational teaching of programming languages.

“In the teaching segment, a teacher used the PPT that came with the textbook. This PPT was rather redundant, with more text than graphics. The expert pointed out this issue to him. From a professional standpoint, there was no problem with the content, but it was mediocre in terms of interest and inspiration. To present to students, one must first be interested and provide a situational demonstration of programming applications. This can show what can be done and allow everyone to understand its application through examples around them. Otherwise, it’s easy to become rote teaching. For students of different age groups, it’s important to teach according to their aptitude and add some fresh elements. From various angles, some issues with heuristic teaching were raised.”

The lack of research skills and the challenge of time and energy distribution are the main factors hindering Xiaofeng’s learning and change. At this stage, although Xiaofeng began to agree with teachers doing research, the lack of research skills and unfamiliarity with research methods still constitute a barrier to Xiaofeng’s learning. Xiaofeng mentioned in the interview that she was confused about the use of research methods. Xiaofeng’s research project is to strengthen situational language teaching in programming education. Before conducting research, Xiaofeng’s teaching philosophy mainly focused on theoretical teaching and relatively despised practical teaching, focusing on doing a lot of problems and explaining code. However, the situational teaching of programming language itself (including knowledge, skills, etc.) was not handled well enough, such as less guidance for students to explicitly learn programming language basics and not paying enough attention to guiding students to transfer and use programming languages. When completing the research, Xiaofeng consciously strengthened

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situational programming teaching in information technology education, and there were obvious changes at both the conceptual and practical levels, indicating that Xiaofeng's cognition is undergoing qualitative changes.

Before the research, Xiaofeng's cognitive system was in a state of balance, with smooth teaching ideas and good practical status, without obvious cognitive conflicts or dilemmas. In the process of implementing research, Xiaofeng participated in open classes and evaluation activities, wrote proposals, communicated with tutors by email, revised proposals, prepared and implemented research classes, implemented 'literature circles', wrote midterm reports and participated in defense activities, talked with tutors face-to-face and other learning activities. In these learning activities, Xiaofeng's cognitive system experienced multiple disturbances (disturbances include different viewpoints conveyed by lecturers, tutor feedback impacting inherent thinking, 'stalled' research plans, 'cold treatment' of expert opinions, 'literature circle' students not cooperating, reports being refuted by the guide team, academic tutors providing deep guidance). When a disturbance event occurs, the cognitive system responds accordingly, enters an adjustment period, then enters a stable period (that is, after a disturbance event occurs, teachers' cognition tends to maintain the status quo and resist external interference), then enters an adjustment period again and gradually enters a reorganization period. In this process, teachers cognition undergoes obvious changes to a large extent. Specifically manifested as Xiaofeng becoming aware of practical problems and gaining new understanding of practical problems. Subsequently increased language focus exercises and optimized reading-writing combined teaching design. Gradually deepened understanding of learning process and principles. Re-characterized practical problems and consciously regulated subsequent teaching practice. When completing the research, Xiaofeng's cognitive system gradually broke the old balance state and began to establish a new balance state. Specifically manifested as Xiaofeng changing her teaching philosophy and practice and updating her understanding of learning laws. Basically achieved the update and transformation of personal theory.

Teachers cognitive changes emerge from interactions within the system and between systems. The internal interactions affecting Xiaofeng's cognitive changes mainly include interactions between teacher knowledge and teacher reflection; cross-interactions between teacher experience, reflection and practice; cross-interactions between teacher knowledge, beliefs and other individual elements (such as identity and motivation). The interactions between systems affecting Xiaofeng's cognitive changes mainly come from large system perception and school classrooms. Specifically include: expert opinions and tutor guidance etc., conflicts between past experiences and current research activities; poor communication between university experts and frontline teachers; project learning activity organization forms etc., school institutional culture (research administrative orientation), education policies and systems (college entrance examination), challenges of time-energy distribution for teachers' teaching-research etc.

As learning activities continue to occur along with disturbance events, elements inside-outside systems (i.e., influencing factors) as well as their interaction relationships continue to change; opportunities for teacher learning continue to emerge. Looking at the learning process from various interaction situations within systems: factors promoting Xiaofeng's learning occurrence (and their combinations) include experts providing new viewpoints-ideas; teacher's own knowledge base-experience; teacher reflection habits; practicing researcher role; project requirements etc.; factors hindering Xiaofeng's learning occurrence (and their combinations) include past research experiences; insufficient reform motivation; one-sided understanding of teacher-research relationship; time-energy constraints; college entrance examination policy etc.

V. Conclusion

This study, based on the perspective of complex dynamic system theory, intends to use a case study method to conduct research for about 6 months on the process of a secondary school IT teacher's professional learning through research, collecting various data such as interviews, observations, reflective journals, artifacts, etc. It aims to track and depict the process of the teacher's learning and cognitive change, and finally interpret the complex dynamic characteristics and systematic nature of this process. In this way, it aims to promote theoretical innovation in domestic IT teacher learning and professional development research. At the same time, important concepts in complex dynamic system theory (such as perturbation, self-organization, emergence, imbalance, etc.) also need to be deepened and specified, and the applicability and operability of complex dynamic system theory in teacher learning research needs to be enhanced. This research will provide important insights for the training and professional development practices of university IT teachers.

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