

**Examining Teachers' Perceptions about Teaching Difficult Concepts in Biology in  
Senior Secondary School Curriculum in Kazakhstan**

Sagyndyk Sagadinov

Master of Science  
in  
Educational Leadership

Nazarbayev University Graduate School of Education

April, 2025

## Ethical Approval



53 Kabanbay Batyr  
Ave. Astana 010000  
Republic of  
Kazakhstan Date: 24  
October, 2024

Dear: Sagyndyk Sagadinov

This letter now confirms that your research project titled:

Examining Teachers' Perceptions about Teaching Difficult Concepts in Biology in Senior  
Secondary School Curriculum in Kazakhstan

---

has been approved by the Graduate School of Education Ethics Committee of  
Nazarbayev University.

You may proceed with contacting your preferred research site and commencing your  
participant recruitment strategy.

Yours sincerely,

Dr Kairat Kurakbayev

**On behalf of:**

Dr Syed Abdul Manan, *PhD*  
Chair, GSE Ethics Committee Graduate  
School of Education  
Nazarbayev University

Block C3, Room 5011  
Office: +7(7172)6016  
Mobile: +77079240053  
email: [syed.manan@nu.edu.kz](mailto:syed.manan@nu.edu.kz), [gse.irec@nu.edu.kz](mailto:gse.irec@nu.edu.kz)

## CITI Training Certificate



Completion Date 27-May-2024  
Expiration Date 27-May-2027  
Record ID 62953598

This is to certify that:

**Sagyndyk Sagadinov**

Has completed the following CITI Program course:

Not valid for renewal of  
certification through CME.

**Social & Behavioral Research - Basic/Refresher**  
(Curriculum Group)

**Social & Behavioral Research - Basic/Refresher**  
(Course Learner Group)

**1 - Basic Course**  
(Stage)

Under requirements set by:

**Nazarbayev University**

**CITI**  
Collaborative Institutional Training Initiative

101 NE 3rd Avenue, Suite 320  
Fort Lauderdale, FL 33301 US  
[www.citiprogram.org](http://www.citiprogram.org)

Generated on 27-Apr-2025. Verify at [www.citiprogram.org/verify/?w07218dd1-5bde-4c23-9711-3b4f149e435a-62953598](http://www.citiprogram.org/verify/?w07218dd1-5bde-4c23-9711-3b4f149e435a-62953598)

### Author Agreement

By signing and submitting this license, I **Sagyndyk Sagadinov** grant to Nazarbayev University (NU) the non-exclusive right to reproduce, convert (as defined below), and/or distribute my submission (including the abstract) worldwide in print and electronic format and in any medium, including but not limited to audio or video.

I agree that NU may, without changing the content, convert the submission to any medium or format for the purpose of preservation. I also agree that NU may keep more than one copy of this submission for purposes of security, back-up and preservation.

I confirm that the submission is my original work, and that I have the right to grant the rights contained in this license. I also confirm that my submission does not, to the best of my knowledge, infringe upon anyone's copyright.

If the submission contains material for which I do not hold copyright, I confirm that I have obtained the unrestricted permission of the copyright owner to grant NU the rights required by this license, and that such third-party owned material is clearly identified and acknowledged within the text or content of the submission.

IF THE SUBMISSION IS BASED UPON WORK THAT HAS BEEN SPONSORED OR SUPPORTED BY AN AGENCY OR ORGANIZATION OTHER THAN NU, I CONFIRM THAT I HAVE FULFILLED ANY RIGHT OF REVIEW OR OTHER OBLIGATIONS REQUIRED BY SUCH CONTRACT OR AGREEMENT.

NU will clearly identify my name(s) as the author(s) or owner(s) of the submission, and will not make any alteration, other than as allowed by this license, to your submission.

I hereby accept the terms of the above Author Agreement.

Author's signature:

Date: 27.04.2025



### **Declaration**

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, or substantial proportions of material which have been submitted for the award of any other course or degree at NU or any other educational institution, except where due acknowledgment is made in the thesis. This thesis is the result of my own independent work, except where otherwise stated, and the views expressed here are my own.

Author's signature:

Date: 27.04.2025

*Saga*

## **Abstract**

This study investigates the challenges biology teachers in Kazakhstan's senior secondary schools face amid recent educational reforms. Through a mixed-methods approach, involving a survey of 113 teachers and interviews with nine educators of varying experience, the research uncovers significant findings. Results highlight widespread concerns over insufficient resources, particularly in rural areas, and professional development that often lacks relevance to advanced biology topics. Teachers also noted curriculum demands that outpace student readiness. Despite these obstacles, educators demonstrate adaptability, employing diverse strategies to enhance student understanding. The findings advocate for improved resource allocation, targeted training, and curriculum adjustments to better support teachers and strengthen biology education in Kazakhstan.

### Аңдатпа

Бұл зерттеу Қазақстандағы жоғары сыныптардағы биология пәні мұғалімдерінің соңғы білім беру реформалары аясында кездестіретін кедергілерді зерттейді. Аралас әдісті қолдана отырып, 113 мұғалімге сауалнама және әртүрлі жұмыс өткілі бар тоғыз педагогпен сұхбат жүргізілді. Бұл зерттеу нәтижесінде маңызды мәлімет анықталды. Мұғалімдердің пайымдауынша, ресурстардың жетіспеушілігі және күрделі биологиялық тақырыптарға сәйкес келмейтін кәсіби даму сабақ сапасына кері әсерлерін береді. Мұғалімдер сонымен қатар оқу бағдарламаларының оқушылардың дайындық деңгейіне сәйкес еместігін атап өтті. Осы қиындықтарға қарамастан, педагогтар оқушылардың түсінігін жақсарту үшін түрлі тәсілдерді қолдана отырып, бейімделеді екен. Нәтижелер мұғалімдерді қолдау және биология пәні бойынша білім сапасын арттыру үшін ресурстарды дамыту, дайындық курстарын бейімдеу және оқу бағдарламаларын түзету қажеттігін көрсетеді.

### **Аннотация**

Темой исследования является изучение трудностей, с которыми сталкиваются учителя биологии в старших классах Казахстана на фоне недавних образовательных реформ. Используя смешанный метод исследования, включающий опрос 113 учителей и интервью с девятью педагогами с разным опытом работы, данное исследование выявляет важные данные. По мнению учителей, нехватка ресурсов и недостаточная актуальность профессионального развития для учебного плана по предмету негативно влияют на качество уроков биологии. Учителя также отметили несоответствие учебных программ уровню подготовки учеников. Несмотря на это, педагоги проявляют гибкость, применяя разные подходы для улучшения усвоения учебного материала. Результаты подчеркивают необходимость улучшения распределения ресурсов, целенаправленной подготовки и корректировки учебных программ для поддержки учителей и повышения качества биологического образования.

## Table of Contents

Ethical Approval.....	i
CITI Training Certificate.....	ii
Author Agreement.....	iii
Declaration.....	iv
Abstract.....	v
Аңдатпа.....	vi
Аннотация.....	vii
Chapter 1: Introduction.....	1
Background and Context of the Study.....	1
Complexity of Biological Concepts and Challenges in Teaching Biology.....	2
Educational Reforms in Kazakhstan.....	2
Teacher Professional Development and Support.....	3
Innovative Teaching Strategies and Resources.....	4
Research Questions.....	4
Study Outline.....	6
Chapter 2: Literature Review.....	7
The Complexity of Teaching High School Biology.....	7
Kazakhstan's Educational Reforms and STEM Integration.....	9
Teacher Professional Development and Support.....	11
Innovative Teaching Strategies and Resources.....	12
Gaps in the Literature and Conclusion.....	14
Conceptual Framework.....	14
Teacher Beliefs and Strategies.....	15
Resource and Curriculum Constraints.....	16
Instructional and Professional Development Needs.....	16
Chapter 3: Methodology.....	19
Research Design.....	19
Quantitative Phase.....	20
Sampling Strategy.....	20
Survey Instrument.....	21
Data Collection Procedure.....	23
Data Analysis.....	23
Qualitative Phase.....	24
Sampling Strategy.....	24
Data Collection.....	25
Data Analysis.....	25
Integration of Quantitative and Qualitative Data.....	26
Ethical Considerations.....	26
Limitations and Delimitations.....	27

Conclusion.....	28
Chapter 4: Findings.....	29
Quantitative Phase.....	29
Demographic Profile of Respondents.....	29
Teaching Experience with Difficult Biology Concepts.....	30
Use of Resources and Teaching Strategies.....	34
Professional Development and Support.....	36
Summary of Quantitative Phase.....	39
Qualitative Phase.....	39
Participants' Demographic Information.....	40
Theme 1: Most Difficult Biology Topics to Teach.....	41
Theme 2: Strategies for Overcoming Teaching Challenges.....	44
Theme 3: The Role of Resources and Technology in Teaching Biology.....	47
Theme 4: Professional Development and Support for Biology Teachers.....	49
Recommendations for Improving Biology Education.....	52
Qualitative Phase Summary.....	55
Chapter 5: Discussion.....	56
Influence of Resource Adequacy, Professional Development, and Curriculum Comfort on Teachers' Confidence.....	56
Quantitative Findings.....	56
Qualitative Findings.....	57
Theoretical Connection.....	58
Interpretation.....	59
Teachers' Perceptions of Support and Professional Development.....	60
Quantitative Findings.....	60
Qualitative Findings.....	61
Theoretical Connection.....	61
Interpretation.....	63
Strategies and Resources Used to Teach Difficult Biology Concepts.....	64
Quantitative Findings.....	64
Qualitative Findings.....	64
Theoretical Connection.....	65
Interpretation.....	66
Implications for Biology Education in Kazakhstan.....	67
Systemic Challenges.....	67
Teachers' Recommendations.....	68
Contextual Relevance.....	68
Policy and Practice.....	68
Chapter 6: Conclusion.....	70
Restatement of the Research Problem and Objectives.....	70
Summary of Key Findings.....	70

Implications and Theoretical Contributions.....	71
Limitations and Future Research Directions.....	71
Reflective Closing.....	72
References.....	73
Appendices.....	83
Appendix A: Declaration of the Use of Generative AI.....	83
Appendix B: Survey Instrument.....	85
Appendix C: Interview Instrument.....	91

**List of Tables**

Table 1 <i>Demographics of Survey Participants (n = 113)</i>	29
Table 2 <i>Which of the following topics from the biology curriculum for grades 7–11 do you find most difficult to teach?</i>	31
Table 3 <i>This factor contributes to the difficulty of teaching biology topics.</i>	33
Table 4 <i>Which of the following resources do you use to teach biology?</i>	34
Table 5 <i>How often do you use digital tools (.eg., simulations, online platforms) to assist with teaching difficult biology topics?</i>	35
Table 6 <i>I feel that I have adequate access to the resources and equipment needed to effectively teach complex biology topics.</i>	36
Table 7 <i>During the last 12 months, did you participate in any of the following professional development activities?</i>	36
Table 8 <i>To what extent do you agree that professional development has been useful in improving your ability to teach difficult concepts in biology?</i>	37
Table 9 <i>What type of support would be most helpful for you in teaching difficult biology topics?</i>	38
Table 10 <i>Demographics of Interview Participants</i>	40

**List of Figures**

Figure 1 <i>Conceptual Framework</i>	17
Figure 2 <i>Triangulation design: convergence model</i>	19

## **Chapter 1: Introduction**

Biology remains a cornerstone of the senior high school curriculum, providing students with a comprehensive understanding of life sciences in all secondary schools across Kazakhstan. As advancements in biotechnology, biomedicine, environmental sciences, and health sciences continue to accelerate worldwide (Labov et al., 2010), the need for high-quality biology education has become more critical than ever.

The rapid development of biology as a multidisciplinary science underscores the importance of equipping high school students with the knowledge and skills needed for future careers and informed citizenship (Loehr et al., 2012). The current trend in high school biology curriculum development reflects the integration of multiple biological disciplines, such as genetics, biotechnology, bioengineering, and molecular biology, further emphasizing the demand for teacher preparation and ongoing professional development (Carvalho et al., 2020).

The purpose of this study is to investigate the challenges faced by biology teachers in Kazakhstan when teaching complex concepts at the senior secondary level. Specifically, this research seeks to explore the perceptions and experiences of biology teachers to identify the most difficult topics, assess the effectiveness of current teaching methods, and propose strategies and support systems that could enhance biology education in Kazakhstan.

### **Background and Context of the Study**

The recent reformations of secondary education curriculum in Kazakhstan was aimed to transform the educational landscape to a more student-oriented environment with the change in pedagogical practices according to the renewed content of education introduced by the government (McLaughlin et al., 2023). The implemented curriculum

brought numerous changes to existing curriculum, renovating the contents of core subjects, including STEM subjects such as biology (Suleimenova et al., 2018).

### ***Complexity of Biological Concepts and Challenges in Teaching Biology***

Despite the importance, teaching biology poses numerous challenges because of the complexity of certain concepts (Carvalho et al., 2020). Teaching topics such as biochemistry of biomolecules, photosynthesis, molecular genetics and DNA sequencing requires deep understanding and ability to transfer the knowledge in an accessible manner to high school students (Koba & Tweed, 2009). The complexity is in the difficulties for both teachers and students, highlighting the need for the assessment of high school educational programs to identify particular topics of challenge and the ways to address them (Sadera et al., 2020).

The challenges faced by teachers are not only limited to updates in content of the course and include the lack of resources and lab materials, varying levels of student preparedness, and the need to keep on track with scientific advancements (Boakye & Ampiah, 2017). In Kazakhstan, it is compounded by the bilingual nature of society, recent educational reforms aimed to improve STEM education, and new requirements for teaching and learning methodologies (Akhmetova & Murzalinova, 2018). This study aims to investigate biology teachers' content knowledge, professional training, and the specific challenges they face in delivering difficult biological concepts in senior secondary classrooms. By focusing on these areas, the study seeks to identify the most challenging topics, evaluate the effectiveness of current teaching methods, and explore the support systems necessary for improving biology education in Kazakhstan.

### ***Educational Reforms in Kazakhstan***

There is a logical possibility that the revised curriculum not only changed the content of biology, but also raised the need for more advanced equipment and professional

development of teachers due to the addition of topics about advanced technology and scientific discoveries in biological fields (Azhmukhambetov, 2020). In the positive sense, it can provide students with novel content and encourage them to learn science and technology actively but at the same time increases the teacher training demands. This approach requires deep research, analysis, and discussion to find the best methodology of teaching and learning high school biology.

Kazakhstan's embrace of an integrated STEM curriculum reflects a broader global shift toward interconnected learning experiences (Almukhambetova, 2025). Teachers are now encouraged to weave together concepts from biology, chemistry, physics, and mathematics, creating rich learning tapestries that mirror real-world scientific inquiry (McLaughlin et al., 2023). While this interdisciplinary approach helps students grasp complex scientific concepts more holistically, it presents a significant challenge for educators who have traditionally taught these subjects in isolation. The transition demands not only extensive professional development but also a fundamental shift in teaching philosophy, as educators learn to bridge traditional subject boundaries in their daily practice.

### ***Teacher Professional Development and Support***

The development and implementation of new curricula and teaching methodologies for core secondary school courses require robust professional development programs for local teachers (Kennedy, 2016). In Kazakhstan, efforts have been made towards teacher support and training through various initiatives, effectiveness of which are yet to be evaluated after a renewed curriculum has been implemented (McLaughlin et al., 2023). This study will explore the current professional development opportunities available to biology teachers from their viewpoint to understand how biology teachers navigate the challenges of teaching difficult concepts in the current high school curriculum.

Understanding of how teachers perceive these professional development programs and whether they feel prepared to deliver the knowledge meeting the demands of the new curriculum is highly valuable. This study will evaluate the alignment between provided support and the actual needs of biology teachers, which will help to identify gaps and nuances (Owens et al., 2018).

### ***Innovative Teaching Strategies and Resources***

The complexity of teaching modern biological concepts and the emphasis on critical thinking and problem solving skills is accompanied by the need to use up-to-date resources, materials, equipment, and teaching techniques. This study will examine the availability and utilization of such resources in Kazakhstan's secondary schools, including:

1. Interactive digital learning tools and simulations
2. Advanced laboratory equipment for practical demonstrations
3. Collaborative learning platforms and project-based learning approaches
4. Integration of real-world applications and case studies

By understanding how biology teachers perceive and use these resources it is possible to identify the challenges they face and ways to develop effective support systems for biology teachers in Kazakhstan.

### **Research Questions**

To guide this study, the following research questions have been formulated:

1. To what extent do resource adequacy, participation in professional development, and comfort with the curriculum influence biology teachers' confidence in teaching complex concepts in senior secondary schools in Kazakhstan?

In Kazakhstan's upper secondary schools, biology teachers need reliable resources, effective training, and a strong grasp of the curriculum to feel confident when teaching

challenging topics. Access to tools like lab equipment and digital aids helps them bring abstract ideas to life, while professional development keeps their skills sharp. Familiarity with the curriculum gives them the assurance to guide students through tough concepts. When teachers feel supported in these ways, they're better equipped to spark curiosity and boost learning, making this a key focus for improving biology education (Tekkaya et al., 2001).

2. How do teachers perceive the support and professional development opportunities available to them in light of the new curriculum requirements?

The recent educational reforms in Kazakhstan, including the introduction of a renewed STEM curriculum, have changed the way biology is taught. Teachers are expected to adapt to new methodologies, integrate advanced technologies, and deliver more complex content. This question seeks to explore whether teachers feel adequately supported in meeting these new demands, focusing on the availability and effectiveness of professional development programs. Identifying gaps between the training provided and teachers' actual needs will offer insights into how professional development can be better aligned with the curriculum changes.

3. What strategies and resources do teachers currently employ to overcome the challenges in teaching difficult biology concepts?

It is critical to understand what teachers themselves believe would help them in delivering complex biological topics more effectively. This question seeks to gather direct input from teachers regarding the resources they need, whether in terms of teaching materials, laboratory equipment, or access to modern digital tools. By capturing the teachers' perspectives, this study aims to develop a more comprehensive understanding of the practical and infrastructural challenges they face, and to recommend targeted solutions for improving biology education in Kazakhstan.

By addressing these questions, this study aims to provide a comprehensive understanding of the current state of biology education in Kazakhstan's senior secondary schools and pave the way for targeted improvements in teacher support and educational practices.

### **Study Outline**

This study aims to explore the current state of biology education in Kazakhstan's senior secondary schools. By examining the challenges faced by biology teachers, evaluating the effectiveness of professional development programs, and understanding the strategies and resources teachers use, this research helps identify areas that need improvement. The findings provide valuable insights into gaps in curriculum implementation, teacher training, and resource allocation, paving the way for practical solutions to support educators and enhance biology education.

The structure of the study is designed to address these goals step by step. Chapter 2 reviews the existing literature on the challenges of teaching biology, the impact of educational reforms, and the importance of innovative teaching strategies and professional development, while identifying gaps that this study seeks to fill. Chapter 3 outlines the research methods, including how the data will be collected through surveys and interviews, and the ethical considerations involved. Chapter 4 presents the findings, analyzing what the data reveals about the challenges and strategies of biology teachers. Chapter 5 discusses these findings, linking them to the broader literature and highlighting their implications. Finally, Chapter 6 summarizes the study's key findings and provides recommendations to improve biology teaching practices and support systems in Kazakhstan. This clear and focused structure ensures that the research effectively addresses its objectives and contributes meaningful solutions to the field.

## **Chapter 2: Literature Review**

This chapter reviews existing literature related to the challenges biology teachers face in teaching complex concepts at the senior high school. It aims to provide a foundation for understanding key issues addressed in this study, which include the complexity of advanced biological topics, the implications of recent educational reforms in Kazakhstan, and the role of teacher training and resources in improving the quality of instruction. By exploring global trends and contextual factors specific to Kazakhstan, this literature review identifies gaps in the literature and the need for this research. The chapter also examines innovative teaching strategies and professional development initiatives relevant to improving biology education in the context of curriculum changes.

### **The Complexity of Teaching High School Biology**

Teaching high school biology is accompanied by a set of constant challenges that arise from the nature of biological concepts, curriculum demands, resource constraints, and teacher readiness. These challenges are particularly seen in countries undergoing educational reforms, such as Kazakhstan, where the introduction of trilingual education and STEM-focused revised curricula has changed the educational landscape (McLaughlin et al., 2023). This section analyzes these issues through global and local perspectives and reveals reappearing themes, including the abstract nature of biology, resource limitations, curriculum overload, and inadequate teacher preparation, while also highlighting gaps in the existing approaches to addressing these challenges.

The abstract nature of biology stands out as a central issue for both students and teachers. Topics such as molecular genetics, photosynthesis, and cellular respiration require students to understand processes that are neither visible nor tangible, making these concepts challenging to teach effectively. Research emphasizes the critical role of systems thinking in helping students grasp such topics, yet teachers often lack the training

necessary to foster this skill (Tripto et al., 2018). International studies suggest that tools such as visual aids, models, and interactive simulations can help address these challenges (Etobro & Fabinu, 2017). However, the effective use of such tools depends on their availability, which remains inconsistent in Kazakhstan, especially in rural schools.

Resource limitations are a critical barrier to effective biology teaching in Kazakhstan. Hands-on experiments and laboratory-based instruction is crucial to fostering student understanding of biological concepts. Yet, many schools, particularly in rural areas, lack the laboratory facilities and materials needed for practical lessons (Akhmetova & Murzalinova, 2018). Similar challenges have been reported in other regions, such as Ghana, where limited access to laboratory equipment hinders students' development of science process skills, such as hypothesizing and data analysis (Dah, 2020). For Kazakhstan, it highlights the importance of conducting research into how resource disparities affect biology teaching in the country, which could provide valuable insights into addressing this challenge and ensuring equitable educational opportunities across both urban and rural schools.

Curriculum-related challenges also play a significant role in the experiences of biology teachers. Internationally, biology curricula are often overloaded with content, making it difficult for teachers to achieve depth of understanding within the limited instructional time available. In some situations, as in Brazil, the curriculum includes thousands of concepts, forcing teachers to prioritize breadth over depth (Carvalho et al., 2020). While Kazakhstan has implemented STEM-oriented reforms, these changes have increased the complexity of biology teaching without addressing issues of content overload and alignment with teaching resources (McLaughlin et al., 2023). Misalignment between curriculum standards and available textbooks further complicates the situation, leaving teachers to bridge these gaps on their own (Yu et al., 2022).

Sociocultural and systemic factors also influence the teaching of biology. Gender disparities in STEM interest have been observed in Kazakhstan, with female students less likely to pursue STEM-related careers due to societal norms and family expectations (Almukhambetova A., 2024). Teachers often face the dual challenge of addressing these biases while fostering an inclusive classroom environment that encourages equal participation. Additionally, large class sizes and limited support infrastructure in rural schools further strain teachers' ability to provide individualized attention and effective instruction.

The challenges of teaching high school biology in Kazakhstan require targeted interventions to address resource disparities, revise the curriculum for a better balance between conceptual depth and procedural knowledge, and provide tailored professional development for teachers. This study aims to identify the specific gaps and challenges in these areas, offering a clearer understanding of the barriers faced by educators.

### **Kazakhstan's Educational Reforms and STEM Integration**

This section aims to examine the impact of the educational reforms on STEM education and biology teaching in Kazakhstan. By analyzing the objectives, implementation, and challenges of these reforms, this section highlights how they align with global trends and contextual factors.

Kazakhstan's recent educational reforms reflect an effort to align the national curriculum to global trends in STEM education. Central to these reforms is the updated curriculum initiative, which focuses on critical thinking, problem solving, and practical application of knowledge, particularly in subjects such as biology (Ministry of Enlightenment, 2022). The integration of advanced topics such as molecular biology, biotechnology, and bioinformatics into the biology curriculum reflects the country's ambition to equip students with necessary skills for a success in a knowledge-driven

economy. These reforms aim to foster interdisciplinary connections and prepare students for careers in research, healthcare, and environmental sciences (Zhumabay et al., 2024).

The reforms represent a significant shift from traditional teaching methods to a more dynamic, student-driven approach. Students now engage with biology through hands-on experiences, such as building phylogenetic trees and conducting enzyme kinetics experiments (Ministry of Enlightenment, 2022). This practical approach, coupled with the Renewed Content of Education's (RCE) criteria-based assessment system, encourages students to think critically rather than simply memorize facts (Ministry of Enlightenment, 2022). However, such ambitious changes require substantial investment in teacher training and resources to succeed.

A notable challenge emerges in the stark contrast between urban and rural educational settings (Tajik et al., 2022). While urban institutions, particularly the well-resourced Nazarbayev Intellectual Schools (NIS), can embrace these changes with modern facilities and comprehensive teacher training, rural schools often struggle with basic infrastructure needs. This disparity threatens to widen the existing educational gap (Zhumabay et al., 2024). The introduction of English Medium Instruction (EMI), part of the now less-emphasized trilingual education model in 10-11 grades, adds another layer of complexity. Though intended to connect students with international scientific discourse, many educators find themselves inadequately prepared to teach complex biological concepts in English (Manan et al., 2024).

Kazakhstan's reform journey mirrors successful educational transformations in other nations while maintaining its unique character. Countries like Finland and Singapore have implemented similar approaches emphasizing interdisciplinary learning and innovation. However, Kazakhstan faces distinctive challenges, as other developing countries, due to its resource distribution patterns (Balta et al., 2023). The country's

diverse linguistic and regional landscape adds another dimension to these reforms, highlighting the need for adaptable solutions that respect local contexts (Zhumabay et al., 2024).

An analysis of Kazakhstan's biology education reforms reveals how resource inequities and teacher preparedness challenges threaten to undermine their ambitious goals. Success of these educational initiatives depends on addressing these systemic barriers to ensure all students, across regional and linguistic contexts, can fully benefit from the modernized education system.

### **Teacher Professional Development and Support**

Professional development serves as the foundation for effective STEM teaching, particularly in biology where teachers must blend complex scientific concepts alongside modern teaching methods. This section explores how targeted training supports biology teachers in Kazakhstan, addressing key challenges identified in this study: teaching difficult topics, implementing effective methods, and adapting to curriculum changes. By examining both global successes and Kazakhstan's unique context, we can better understand how professional development helps teachers meet new curriculum demands and overcome everyday classroom challenges.

Worldwide, successful teacher training emphasizes sustained engagement and practical learning. Finland and Singapore showcase effective approaches through programs that blend inquiry-based learning with technology and peer support (Elster, 2009; Lay et al., 2020). Biology teachers particularly benefit from professional learning communities, which help them tackle challenging topics like molecular biology and evolution (Rozenszajn & Yarden, 2014). These examples offer valuable insights for enhancing biology education in Kazakhstan.

However, Kazakhstan's current training landscape reveals significant disparities. Urban teachers generally have better access to training, though many programs lack depth in advanced topics like biotechnology (Zharylkassyn, 2023). Rural educators face greater hurdles, from travel costs to limited online access. Most existing programs emphasize theory over practice, leaving teachers uncertain about implementing inquiry-based lessons that align with the new curriculum (Makoelle & Burmistrova, 2021). These challenges directly impact teaching quality and student learning outcomes.

Looking forward, several key recommendations emerge from this review. Training programs should focus on helping teachers address difficult biology topics identified in this study, while providing practical tools for diverse classroom settings. Adapted online and hybrid formats could make training more accessible for rural teachers. Additionally, long-term mentoring and professional communities could support sustained teacher growth, particularly in implementing advanced topics and methods (Rozenszajn & Yarden, 2014).

This analysis reveals how professional development directly connects to our research questions about improving biology education in Kazakhstan. Effective training programs are essential for helping teachers identify and address challenging topics, enhance their teaching methods, and overcome systemic barriers. These insights and teachers' feedback guide practical recommendations for strengthening biology education across Kazakhstan's diverse educational landscape.

### **Innovative Teaching Strategies and Resources**

Modern teaching approaches play a vital role in making biology education more effective, especially when teaching complex scientific concepts. This analysis explores how innovative strategies can enhance biology education in Kazakhstan, examining both their potential benefits and implementation challenges.

Digital tools like virtual labs and simulations have proven particularly powerful in global biology education. These technologies help students visualize abstract processes such as enzyme reactions and genetic changes, making complex ideas more tangible (Zulyusri et al., 2023). Problem-based learning also shows promise, engaging students with real-world challenges like environmental conservation and disease patterns, which builds both critical thinking and practical skills (McLure et al., 2022). Research consistently shows these approaches improve learning outcomes, especially for topics requiring broader understanding and cross-subject connections (Rozenszajn & Yarden, 2014).

However, Kazakhstan faces significant hurdles in adopting these methods. Rural schools often lack basic digital infrastructure and resources. Limited internet access and laboratory equipment make it difficult to implement digital tools and hands-on experiments (Ilma et al., 2020). Even well-equipped urban schools struggle with consistent teacher training and support (Zharylkassyn, 2023). These gaps highlight the need for targeted investment in both infrastructure and teacher development.

Yet opportunities exist to adapt these innovative approaches to Kazakhstan's unique needs. Virtual labs offer cost-effective alternatives to physical experiments, allowing students to explore complex procedures like DNA analysis despite resource limitations. Online platforms could connect teachers and students across schools, fostering knowledge sharing and collaborative learning (McLure et al., 2022). Research suggests combining traditional teaching with modern tools can improve student learning without overwhelming teachers with entirely new methods (Zulyusri et al., 2023).

Success in transforming biology education in Kazakhstan depends on addressing resource gaps and teacher preparation while adapting global innovations to local needs. Understanding how teachers currently navigate these challenges provides crucial insights

for developing targeted support and ensuring these innovative strategies benefit all students, regardless of their school's location or resources.

### **Gaps in the Literature and Conclusion**

While this literature review has explored the challenges and opportunities in teaching high school biology, particularly in Kazakhstan, there are still important gaps that need to be addressed. Few studies have looked at how biology teachers are adapting to the updated curriculum or how they manage resource limitations in their schools. There is also limited research on the specific teaching strategies they use and how effective these strategies are in practice. Additionally, the impact of professional development programs designed for biology teachers in Kazakhstan remains unclear, especially in rural areas where access to training is more limited.

These gaps highlight the importance of understanding the real experiences of biology teachers in Kazakhstan, how they overcome challenges, what resources they rely on, and what kind of support they need. This study aims to fill these gaps by exploring the unique context of biology education in Kazakhstan and reveal the barriers teachers face and the solutions that could work for them. Ultimately, this research hopes to contribute to practical improvements in teaching practices and help create a more equitable and effective biology education system for all students.

### **Conceptual Framework**

This section presents the theoretical foundation that guides this study on the challenges of teaching difficult biology concepts in Kazakhstan. Three established theories have been integrated to create a comprehensive framework that addresses the gaps identified earlier. By combining Bandura's Self-Efficacy Theory, Priestley's Teacher Agency Framework, and Kennedy's Professional Development Model, the study examines

three critical dimensions: teacher beliefs and strategies, resource and curriculum constraints, and instructional and professional development needs (Bandura, 1977; Priestley et al., 2015; Kennedy, 2005). These theories offer valuable perspectives for analyzing the complexities of biology education in the Kazakhstani context.

### ***Teacher Beliefs and Strategies***

The effectiveness of biology teaching is deeply influenced by how teachers perceive their own abilities and the instructional approaches they adopt. According to Bandura's Self-Efficacy Theory, people's beliefs about their capabilities significantly impact their performance and behavior (Bandura, 1977). In biology classrooms across Kazakhstan, this manifests clearly: teachers with strong self-efficacy tend to embrace innovative teaching methods, persist when teaching challenging topics like molecular genetics, and adapt more flexibly to classroom obstacles. In contrast, those with lower self-efficacy often avoid difficult content or fall back on memorization-based approaches, which limits student engagement and conceptual understanding. This theoretical lens is particularly valuable for understanding how Kazakhstani teachers navigate the abstract nature of biological concepts while implementing the reformed curriculum.

Priestley's Teacher Agency Framework enriches this perspective by highlighting how teachers exercise professional judgment within their specific contexts (Priestley et al., 2015). It refers to the ability of teachers to make intentional choices and take actions that influence their teaching practices, mostly shaped by their professional knowledge, beliefs, and the contextual factors of their work environment (Priestley et al., 2015). Teacher agency plays a crucial role in shaping instructional decisions, reflecting how educators navigate challenges such as overcrowded classrooms or cultural factors like gender imbalances in STEM fields. In Kazakhstan's diverse educational landscape, this framework

illuminates the complex interplay between teachers' personal beliefs and the external forces that shape their teaching practices.

### ***Resource and Curriculum Constraints***

Biology teachers in Kazakhstan, in general, face significant challenges related to limited resources and overloaded curricula. Priestley's Teacher Agency Framework offers valuable insights here as well, framing teachers' adaptability to these constraints as an expression of their professional agency (Priestley et al., 2015). When teachers lack access to well-equipped laboratories, current textbooks, or face overwhelming curriculum requirements, their ability to implement hands-on or inquiry-based learning is restricted. However, teachers with well-developed agency often find creative solutions—adapting virtual laboratories or utilizing locally available materials—to fulfill curriculum requirements despite these limitations. This theoretical perspective is essential for understanding how Kazakhstani biology teachers respond to systemic barriers and for identifying effective support strategies to enhance their adaptability.

### ***Instructional and Professional Development Needs***

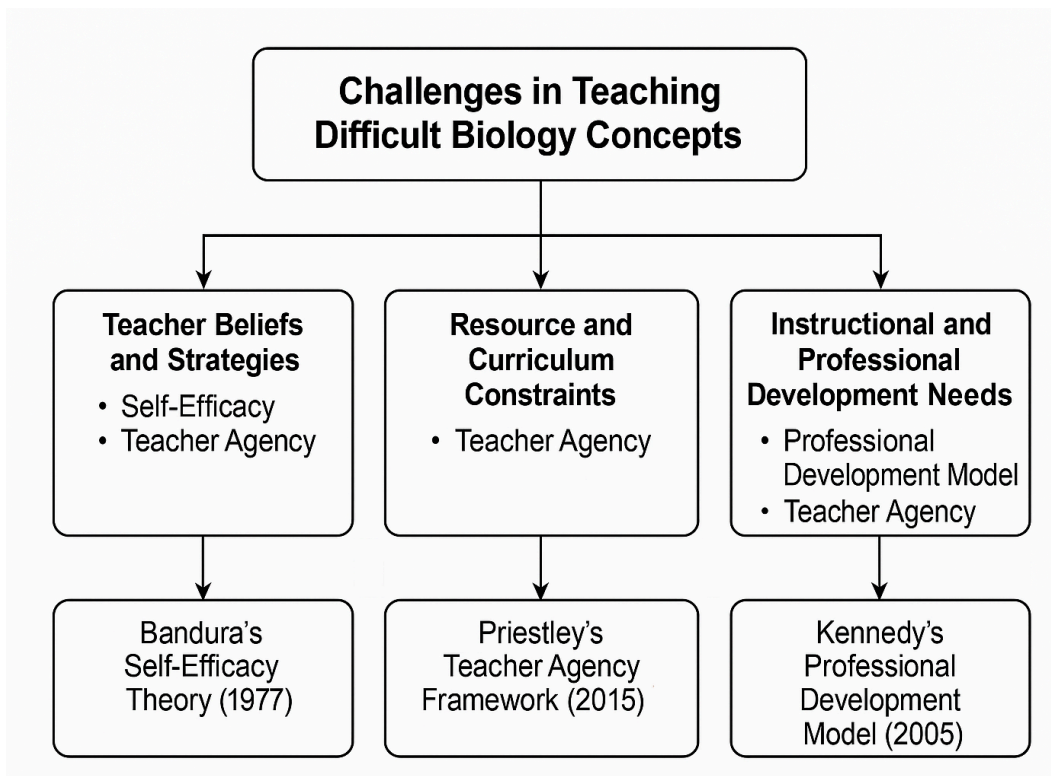
Improving biology instruction in Kazakhstan requires addressing teachers' professional growth needs. Kennedy's Professional Development Model provides a structured approach for analyzing various professional development formats, categorizing them into nine types with transformative models being particularly powerful as they integrate action research, mentoring, and professional learning communities (Kennedy, 2005). These transformative approaches are especially relevant for Kazakhstan's biology teachers, as they promote critical reflection and sustainable changes in teaching practices—crucial for educators adapting to the country's STEM-focused educational reforms. Kennedy's model emphasizes the importance of ongoing, collaborative, and

context-specific professional learning to strengthen teachers' capacity to teach advanced topics such as biotechnology.

Priestley's Teacher Agency Framework complements Kennedy's model by showing how effective professional development enhances teachers' agency (Priestley et al., 2015). When teachers engage in transformative professional learning experiences, they develop greater confidence and skills, enabling them to exercise more agency in their practice. This empowers them to overcome instructional challenges and implement innovative teaching approaches despite resource limitations. Together, these theories highlight the need for professional development that not only builds knowledge but also empowers teachers to meet both curriculum requirements and students' learning needs.

**Figure 1**

*Conceptual Framework (Based on Bandura, 1977; Priestley et al., 2015; Kennedy, 2005).*



This integrated conceptual framework combines psychological (self-efficacy), ecological (agency), and educational (professional development) perspectives to provide a holistic understanding of the challenges facing biology education in Kazakhstan. By grounding the study in these theories, it aims to interpret teachers' lived experiences, identify effective support mechanisms, and address the research gaps outlined in literature review.

### Chapter 3: Methodology

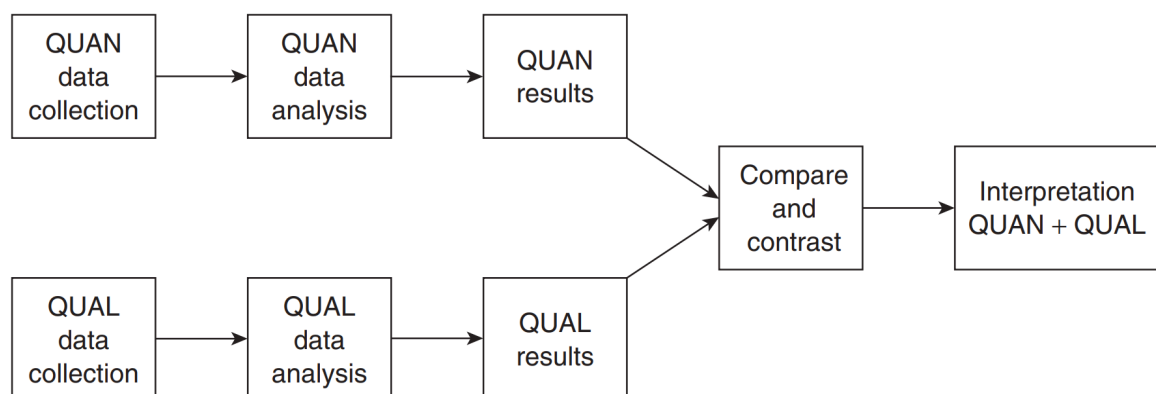
This study employs a mixed-methods approach to investigate the challenges faced by biology teachers in Kazakhstan when teaching complex concepts. The research design combines quantitative and qualitative methods to provide a comprehensive understanding of the issue (Creswell & Plano Clark, 2017). This approach allows for the collection of broad, generalizable data through a large-scale survey, while also gathering in-depth insights through interviews with teachers. The methodology is designed to address the research questions outlined in Chapter 1 and builds upon the literature review presented in Chapter 2.

#### Research Design

The study utilized an explanatory convergent mixed methods design (Creswell & Creswell, 2018). This design involves two phases: a quantitative phase followed by a qualitative phase. The quantitative data is collected first through a survey, and the results inform the development of the qualitative phase, which consists of semi-structured interviews. This design was chosen because it allows for a broad understanding of the challenges faced by biology teachers across Kazakhstan, followed by a more nuanced exploration of these challenges through in-depth interviews.

#### Figure 2

*Triangulation design: convergence model (adapted from Creswell & Creswell, 2018).*



The rationale for using a mixed-methods approach is rooted in the complexity of the research problem. While quantitative data can provide a general picture of the challenges faced by biology teachers, qualitative data can offer insights into the lived experiences of teachers and the context-specific factors that influence their teaching practices. By combining these approaches, we aim to produce a more comprehensive and nuanced understanding of the research problem (Johnson et al., 2007).

## **Quantitative Phase**

### ***Sampling Strategy***

A convenience random sampling method was employed to select participants for the survey, ensuring representation of both urban and rural areas (Cohen et al., 2018). The target population for this study includes secondary school biology teachers from mainstream schools in Kazakhstan. Schools will be randomly selected within different regions of the country, and all biology teachers in the selected schools will be invited to participate in the survey.

The number of schools selected from rural and urban districts were proportional ensuring distributed representation. A minimum number of teachers was not set for individual schools, but efforts will be made to ensure broad participation across schools. This helped to capture the diversity of educational contexts, from urban schools with more resources to rural schools facing different challenges.

To determine the required sample size, power analysis was conducted to ensure statistical significance. In the absence of exact data on the total number of biology teachers in Kazakhstan, estimates will be guided by general teacher population statistics in similar educational contexts. For a population assumed to exceed 1,000 teachers, a sample size of approximately 278 is sufficient to achieve a 95% confidence level with a 5% margin of error (Krejcie & Morgan, 1970). However, considering potential non-responses, it is

planned to distribute the survey to 400-500 teachers to account for expected variations in response rates. Assumptions regarding effect size will be based on previous similar studies in education, where moderate effect sizes have been observed. A response rate of around 50% is anticipated, as supported by survey studies in similar educational settings, although efforts will be made to increase this through follow-up reminders.

Ethical considerations are integral to this sampling approach. Informed consent was embedded within the questionnaire, and participation in the survey will be considered as providing consent. At the beginning of the questionnaire, participants will be provided with clear information about the study's purpose, the voluntary nature of participation, their right to withdraw at any time without consequence, and assurances of confidentiality. Confidentiality will be ensured by anonymizing all survey responses, and raw data will be securely stored on the researcher's institutional Google Drive, which is password-protected and complies with data storage and security standards. No identifying information will be shared in the reporting of the results, and access to the data will be limited to the researcher.

### ***Survey Instrument***

An online survey was developed based on general principles of questionnaire design to ensure clarity, relevance, and alignment with the study's objectives (Cohen et al., 2018). The survey was tailored to the Kazakhstani context, addressing specific challenges faced by biology teachers. It was created using a professional survey platform, such as Qualtrics, to facilitate efficient distribution, secure data collection, and ease of participation.

The survey was divided into five sections, four of which pertained to the quantitative phase of the study: demographics, teaching experience with challenging biology concepts, use of resources and teaching strategies, and professional development

and support. The fifth section was dedicated to collecting contact information for the qualitative phase, which is discussed later in this chapter. Survey instruments can be found in Appendix B.

The survey collected various types of information, starting with demographic data. This section gathered details such as the participants' age, gender, years of teaching experience, educational qualifications, and any specialized training they have received in biology education. Information about school characteristics will also be obtained, including the school's location (whether urban or rural), size, the availability of resources for biology teaching such as laboratory equipment, textbooks, and digital resources, as well as class sizes.

The survey assessed teachers' perceptions of the difficulty of various biology topics by using a 5-point Likert scale, ranging from "not at all difficult" to "extremely difficult." Teachers will rate the difficulty of teaching specific topics within the current Kazakhstani curriculum, including areas such as genetics, cell biology, ecology, evolution, human anatomy, and physiology. These topics have been identified as challenging through the literature review.

Another key focus of the survey were the challenges teachers face in teaching biology. This section utilized both Likert scale questions and multiple-choice items to assess the frequency and severity of challenges, which may include a lack of resources, student misconceptions, time constraints, and difficulties in explaining abstract concepts.

Teachers were also asked about the teaching strategies and resources they frequently use. This part of the survey explored the extent to which teachers rely on different instructional methods, such as lectures, group work, and practical experiments, as well as their use of educational resources like textbooks, online materials, and virtual labs.

In addition, the survey examined teachers' participation in professional development activities. It explored their perceptions of the effectiveness of these activities and identified areas where they feel they need further support or training.

To capture additional insights, the survey included a few open-ended questions, allowing teachers to provide comments or share experiences that may not be covered by the structured questions.

The survey was developed in both Kazakh and Russian to ensure accessibility for all participants. Before full implementation, the survey was piloted with a small group of 10 to 15 teachers to ensure its clarity, relevance, and appropriate length. Feedback from the pilot was mostly positive and was used to refine the survey and ensure its effectiveness.

#### ***Data Collection Procedure***

The survey was distributed electronically to the biology teacher's associations through the Qualtrics platform. Associations' leaders were contacted first to obtain permission and support for the study. Then, individual willing teachers, who filled their contacts in the survey, were invited to participate via email and contact number, with reminder emails sent after one and two weeks to maximize response rates.

The survey was open for five weeks to allow sufficient time for completion. To encourage participation, teachers were offered a summary of the research findings upon completion of the study.

#### ***Data Analysis***

Quantitative data was analyzed using Python programming language to provide a clear understanding of the data and address the study's research questions. The analysis began with descriptive statistics, which summarized key characteristics of the sample. Measures of central tendency and measures of dispersion were calculated to explore

variables like teacher demographics, school resources, and the perceived difficulty of teaching biology topics (Cohen et al., 2018).

To investigate the relationship between teachers' confidence and comfort questions, Spearman's Rank Correlation was utilized. This non-parametric test was selected due to the ordinal nature of the individual Likert scale questions, enabling the evaluation of the strength and direction of the association between these two variables (Field, 2017).

Furthermore, to ensure the reliability of the survey instrument, Cronbach's alpha was calculated for the set of suitable items in the survey. This analysis verified the internal consistency of the scale, which is crucial for the validity of the survey findings (Field, 2017).

Overall, the quantitative analysis aimed to identify patterns and relationships that can inform and complement the qualitative phase of the study.

## **Qualitative Phase**

### ***Sampling Strategy***

Purposive sampling will be used to select nine biology teachers for in-depth interviews. These will be divided into three groups based on years of experience: novice (0-5 years), experienced (6-15 years), and veteran (15+ years). This stratification allows for exploration of how challenges and strategies may differ with experience levels (Patton, 2015).

Participants for the qualitative phase will be selected from among the survey respondents who indicate willingness to participate in follow-up interviews. Selection criteria will include:

- Representation from different experience levels
- Geographical diversity (urban/rural, different regions of Kazakhstan)
- Variation in reported challenges and teaching strategies

### ***Data Collection***

Semi-structured interviews will be conducted with the selected teachers. The interview protocol will be developed based on the results of the quantitative phase and will explore: (1) Detailed experiences with teaching challenging biology concepts; (2) Strategies used to overcome difficulties; (3) Perceptions of available resources and support; (4) Reflections on professional development needs and (5) Suggestions for improving biology education in Kazakhstan.

Interviews will be conducted in the teacher's preferred language (Kazakh or Russian) and will last approximately 60-90 minutes. They will be audio-recorded with the participant's consent and later transcribed for analysis. Interviews will be conducted either in person or via video conferencing, depending on logistical considerations and participant preference.

In addition to the interviews, participants will be asked to share any relevant documents (e.g., lesson plans, assessment materials) that illustrate their approach to teaching challenging biology concepts. These documents will provide additional context for the analysis.

### ***Data Analysis***

Qualitative data will be analyzed using thematic analysis as outlined by Braun and Clarke (2006). This process will begin with familiarization with the data, where transcripts will be read and re-read to develop a thorough understanding of the content. Following this, the data will be systematically coded to identify relevant features. These initial codes will then be organized and collated into potential themes. The emerging themes will be reviewed to ensure they align with both the coded extracts and the entire data set. Once reviewed, each theme will be clearly defined and named to capture its essence.

The final step in the analysis will involve the production of the report, where vivid and compelling examples from the data will be extracted and linked back to the research questions and the literature. NVivo software will be used to facilitate the coding process and the development of themes. The qualitative data analysis will follow a thematic analysis approach, as outlined by Braun and Clarke (2006), involving six structured steps: familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the final report.

### **Integration of Quantitative and Qualitative Data**

The findings from both phases will be integrated to provide a comprehensive understanding of the challenges in teaching difficult biology concepts in Kazakhstan. This integration will follow the guidelines provided by Fetters et al. (2013) for connecting, building, and merging mixed methods data.

The integration will occur at multiple levels:

1. Design level: The quantitative results will inform the selection of participants and the development of interview questions for the qualitative phase.
2. Methods level: The qualitative data will be used to explain and elaborate on the quantitative findings.
3. Interpretation and reporting level: The results from both phases will be synthesized to address the research questions comprehensively. This may involve creating joint displays that present quantitative and qualitative data together to illustrate key findings.

### **Ethical Considerations**

Ethical approval for this study will be sought from both the relevant educational authorities in Kazakhstan and the researcher's institutional review board. The study will

adhere to established ethical guidelines for educational research, ensuring that all procedures meet international standards for ethical practice.

Informed consent will be obtained from all participants, who will be provided with detailed information about the study's purpose, procedures, and the use of their data. Written consent will be required to confirm their understanding and voluntary participation. Confidentiality and anonymity will be strictly maintained, with participants' data anonymized and pseudonyms used in reporting. All raw data will be securely stored, accessible only to the research team, and handled in accordance with data protection regulations.

Participants will be fully informed of their right to withdraw from the study at any time, without any penalty, ensuring that their involvement remains entirely voluntary. The research design will also account for the cultural and linguistic diversity of Kazakhstan, demonstrating sensitivity to these factors to ensure respectful and inclusive participation throughout the study.

### **Limitations and Delimitations**

While the mixed-methods approach provides a comprehensive understanding of the research problem, several limitations should be acknowledged. First, the study adopts a cross-sectional design, offering a snapshot of the current situation rather than capturing changes over time, as would be possible in a longitudinal study. Additionally, the reliance on self-reported data in both the quantitative and qualitative phases may introduce bias, as participants' responses could be influenced by factors such as social desirability or personal interpretation. Furthermore, although the qualitative phase yields rich, in-depth insights, it is limited by the small number of participants, which may restrict the generalizability of the findings to all biology teachers in Kazakhstan.

Delimitations of the study include its specific focus on secondary school biology teachers in Kazakhstan, thereby excluding primary school teachers and educators from other disciplines. This deliberate focus is intended to concentrate on the particular challenges faced in secondary biology education, but it limits the broader applicability of the findings across different educational levels or subjects.

### **Conclusion**

This chapter has outlined the mixed-methods research design that will be used to investigate the challenges faced by biology teachers in Kazakhstan when teaching complex concepts. The combination of a large-scale survey and in-depth interviews will provide both breadth and depth in understanding this important issue. The methodology has been designed to address the research questions comprehensively while adhering to ethical research principles.

## Chapter 4: Findings

This chapter presents the findings derived from both the quantitative survey and qualitative interviews conducted with biology teachers in Kazakhstan. The results are structured according to the data collection procedures, integrating statistical data from the surveys with thematic insights obtained through interviews. This dual approach aims to provide a comprehensive understanding of the challenges faced by biology teachers when teaching complex concepts, as well as the strategies they employ to address these challenges.

### Quantitative Phase

The quantitative phase of this study involved the distribution of a survey among biology teachers across Kazakhstan. A total of 121 biology teachers were initially contacted, and after providing informed consent, 113 participants agreed to take part in the study. Participants were informed of their right to withdraw at any time, ensuring ethical compliance throughout the research process.

### *Demographic Profile of Respondents*

The demographic profile questionnaire included questions related to gender, years of experience, school type, and class size. These demographic factors are critical in understanding the variability in teachers' perceptions and experiences, potentially contributing to disparities in teaching practices.

The demographic data is presented in Table 1, using frequency (n) and percentage (%) formats, reflecting the respondents' voluntary participation and their ability to skip questions if desired.

**Table 1**

### *Demographics of Survey Participants (n = 113)*

Category	Subcategory	Frequency(n)	Percentage (%)
----------	-------------	--------------	----------------

Gender	Female	0.85	85%
	Male	0.15	15%
Years of Experience	0–5 years	0.25	25%
	6–10 years	0.3	30%
	11–15 years	0.2	20%
	>15 years	0.25	25%
School Type	Urban	0.6	60%
	Rural	0.4	40%
Class Size	Less than 20 students	0.2	20%
	21–30 students	0.65	65%
	31–40 students	0.1	10%
	More than 40 students	0.05	5%

An uneven distribution is evident in the gender composition of the respondents, with females constituting 85% of the sample. This disparity aligns with broader trends in Kazakhstan's educational sector, where male teachers represent approximately 18.95% of secondary school educators, as reported by the Ministry of Education (2024). Additionally, an uneven distribution in class sizes is observed, with the majority of biology classes ranging between 21 and 30 students. This variation in class size may significantly influence teaching experiences and could be further analyzed statistically to determine its impact on teaching effectiveness.

In summary, the demographic profile of the respondents provides valuable context for interpreting the subsequent findings, highlighting potential influences of gender, experience, school type, and class size on teaching practices and challenges in the Kazakhstani educational setting.

### ***Teaching Experience with Difficult Biology Concepts***

The second section of the quantitative survey focused on identifying the biology topics that teachers perceive as challenging to teach, categorized by the grade level they

instruct. While the mean difficulty scores provide valuable insights into the relative complexity of various topics, it is essential to emphasize that the most critical aspect of these findings lies not in the absolute mean scores themselves but in the disparity between topics. This disparity highlights the relative challenges teachers face when teaching specific concepts compared to others within the same grade level.

To assess the difficulty of teaching these topics, respondents rated their experiences on a 5-point Likert scale, where:

- 1 = Very easy to teach
- 2 = Easy to teach
- 3 = Moderately difficult to teach
- 4 = Difficult to teach
- 5 = Very difficult to teach

The mean difficulty score for each topic was calculated based on aggregated responses. However, it is important to note that this question does not fully capture whether a teacher considers a topic inherently difficult; rather, it reflects the teacher's perception of difficulty on a relative scale compared to other topics within the same grade. Thus, the disparities between topics are more informative than the absolute scores themselves.

**Table 2**

***Which of the following topics from the biology curriculum for grades 7–11 do you find most difficult to teach?***

Grade	N	Topic	Mean Difficulty Score (out of 5)
Grade 7	1	Cell Biology	3.08
	2	Classification of Organisms	3.19
	3	Transport in Plants	3.27

	4	Movement	3.28
	5	Water and Organic Compounds	3.31
	6	Coordination and Regulation	3.34
	7	Excretion	3.41
	8	Photosynthesis	3.45
	9	Respiration	3.46
	10	Ecosystems	3.47
Grade 8	1	Respiration	2.61
	2	Biophysics	2.63
	3	Nutrition	2.81
	4	Excretion	2.88
	5	Biodiversity	2.90
	6	Cell Biology	2.92
	7	Transport in Animals	2.99
	8	Molecular Biology	3.10
	9	Coordination and Regulation	3.10
Grade 9	1	Cell Biology	2.24
	2	Reproduction	2.47
	3	Ecology	2.48
	4	Biotechnology	2.53
	5	Evolution & Biodiversity	2.61
	6	Genetics	2.61
	7	Molecular Biology & Biochemistry	2.62
Grades 10-11	1	Human Anatomy & Physiology	2.28
	2	Ecology	2.35
	3	Reproduction & Development	2.52
	4	Genetics & Heredity	2.83
	5	Evolution	2.92
	6	Biotechnology & Bioinformatics	3.04
	7	Molecular Biology & Biochemistry	3.26

---

The relative differences in perceived difficulty highlight the challenges teachers encounter when transitioning between topics within the same grade. A topic with a mean score of 3.26 may not necessarily be universally difficult but could appear so when contrasted with another topic scoring 2.28. Therefore, further research is required to feel the gap in this data.

According to the teachers' responses, several factors contribute to the challenges they face when teaching difficult biological concepts. These factors, ranked by the percentage of teachers who agreed to their contribution, are as follows:

**Table 3**

*This factor contributes to the difficulty of teaching biology topics. (Select all that apply)*

Category	Percentage
Lack of laboratory equipment	62.5%
Complexity of the content	53.8%
Time constraints	48.9%
Lack of student readiness	46.8%
Abstract nature of the concepts	46.3%
Insufficient teaching resources	31%

To assess the reliability of these six items as a scale measuring perceived teaching challenges, Cronbach's alpha was calculated. The alpha value was 0.724, indicating acceptable internal consistency (Field, 2017).

The next two questions in the section examine teachers' levels of confidence when teaching difficult biology concepts and their comfort with the current biology curriculum. The cross-tabulation analysis further underscores the relationship between responses for these two statements. A Spearman rank correlation revealed a significant positive correlation between these variables (Spearman's  $\rho = 0.23$ ,  $p = 0.028$ ), indicating that teachers who feel comfortable with the curriculum are more likely to report higher confidence in explaining complex topics. For instance, 63.6% of teachers who felt "Extremely Comfortable" with the curriculum also "Absolutely Agreed" that they were confident in their teaching abilities. Conversely, teachers expressing discomfort with the curriculum were more likely to report lower confidence.

### ***Use of Resources and Teaching Strategies***

The third section of the survey explored the availability and utilization of teaching resources, as well as the strategies employed by biology teachers in Kazakhstan. The findings from this section are derived from responses to three key questions, providing insight into how teachers use various resources and perceive their adequacy for teaching complex biological concepts.

**Table 4**

***Which of the following resources do you use to teach biology? (Select all that apply)***

Category	Percentage
Online videos or tutorials	80,6%
Textbooks	72,0%
Laboratory experiments	45,2%
Digital simulations or virtual labs	44,1%

Real-world case studies	37,6%
Project-based learning	5,4%

---

The data indicates that online videos or tutorials (80.6%) and textbooks (72.0%) are the most commonly used resources among biology teachers. These findings suggest a reliance on traditional and digital instructional materials to support teaching practices. In contrast, laboratory experiments (45.2%) and digital simulations or virtual labs (44.1%) are utilized less frequently, potentially due to limitations in access to laboratory equipment or familiarity with digital tools. Additionally, real-world case studies (37.6%) are moderately used, while project-based learning (5.4%) is rarely incorporated, highlighting a gap in the adoption of more interactive and student-centered approaches.

**Table 5**

***How often do you use digital tools (.eg., simulations, online platforms) to assist with teaching difficult biology topics?***

Category	Percentage
Never	0%
Rarely	20,4%
Sometimes	28%
Often	38,7%
Always	12,9%

---

The results show that a significant proportion of teachers (38.7% ) use digital tools "Often" to assist with teaching challenging biology topics, while only 12.9% report using them "Always." This suggests that while many teachers recognize the value of digital tools, consistent integration remains limited for some of them, conversely, 20.4% of teachers use these tools "Rarely". Notably, no teacher reported "Never" using digital tools, suggesting universal awareness of their potential utility in teaching.

**Table 6**

*I feel that I have adequate access to the resources and equipment needed to effectively teach complex biology topics.*

Category	Percentage
Extremely inadequate	3,2%
Somewhat inadequate	33,3%
Neither adequate nor inadequate	21,5%
Somewhat adequate	37,6%
Extremely adequate	4,3%

Teachers' perceptions of resource adequacy vary significantly. A notable proportion (33.3%) feel that their access to resources is "Somewhat inadequate," while an additional 21.5% consider it "Neither adequate nor inadequate." Only 4.3% of teachers perceive their access as "Extremely adequate," pinpointing concerns about resource limitations. These findings align with earlier observations regarding the limited use of laboratory experiments and digital simulations, which may stem from insufficient access to necessary equipment and technology.

### ***Professional Development and Support***

The fourth section of the survey explored teachers' experiences with professional development (PD) activities, their perceptions of PD utility, and the types of support they believe would enhance their teaching quality. The findings provide valuable insights into the current state of PD engagement and highlight areas where additional support is needed.

**Table 7**

*During the last 12 months, did you participate in any of the following professional development activities?*

Category	Percentage
Workshops or seminars focused on biology teaching	81,4%

Observing other teachers' biology lessons (peer observation)	46,5%
Self-guided learning (e.g., reading books, articles, or research papers about teaching biology)	41,9%
Peer collaboration or study groups with other biology teachers	37,2%
Online courses or webinars about teaching methodologies	36,0%
Participation in a professional network or association (e.g., biology teachers' association)	34,9%
Mentoring or coaching by more experienced teachers	25,6%
No, I did not participate in any professional development activities	8,1%
University or academic training programs related to biology	2,3%

The data shows that the majority of teachers (81.4%) participated in workshops or seminars focused on biology teaching, indicating a strong reliance on formal PD opportunities. However, participation rates decline for other forms of PD, such as peer observation (46.5%), self-guided learning (41.9%), and peer collaboration (37.2%). Only a small percentage of teachers engaged in mentoring (25.6%) or university-based training (2.3%). Notably, 8.1% of teachers reported no participation in any PD activities, suggesting potential barriers to access or interest.

### **Table 8**

***To what extent do you agree that professional development has been useful in improving your ability to teach difficult concepts in biology?***

Category	Percentage
Not at all useful	2,4%
Slightly useful	8,2%
Moderately useful	30,6%
Very useful	51,8%
Extremely useful	7,1%

Teachers generally perceive PD as beneficial, with 51.8% reporting it as "Very useful" in improving their ability to teach difficult biology concepts. An additional 30.6% found it "Moderately useful," while only 10.6% (combining "Not at all useful" and "Slightly useful") expressed dissatisfaction. These results indicate that PD initiatives are largely effective but may require enhancements to address the needs of teachers who find them less impactful.

**Table 9**

*What type of support would be most helpful for you in teaching difficult biology topics?*

*(Select all that apply)*

Category	Percentage
Access to better teaching resources (e.g., updated textbooks, digital tools)	57,6%
Access to advanced laboratory equipment	56,5%
Online resources or tutorials for students	51,8%
More professional development opportunities	45,9%
Smaller class sizes	34,1%
Collaboration with other biology teachers from other schools	30,6%

Teachers identified access to better teaching resources (57.6%) and advanced laboratory equipment (56.5%) as the most critical forms of support. Over half of the respondents also requested online resources or tutorials for students (51.8%), highlighting the growing importance of digital tools in education. Additionally, 45.9% of teachers expressed a desire for more PD opportunities, reinforcing the need for ongoing professional growth. While smaller class sizes (34.1%) and inter-school collaboration (30.6%) were less frequently cited, they still represent notable areas of interest.

### ***Summary of Quantitative Phase***

The quantitative phase of the study surveyed 113 biology teachers across Kazakhstan, exploring demographics, teaching challenges, resource use, and professional development experiences. Key findings revealed an uneven gender distribution (85% female), with most teachers having moderate experience (6–10 years) and teaching classes of 21–30 students. Teachers identified several factors contributing to difficulties in teaching complex biology concepts, including lack of laboratory equipment (62.5%), content complexity (53.8%), and time constraints (48.9%). While they frequently relied on online videos (80.6%) and textbooks (72.0%), access to adequate resources and equipment was perceived as inadequate by many. A significant positive correlation was found between teachers' comfort with the curriculum and their confidence in teaching challenging topics (Spearman's  $\rho = 0.23$ ,  $p = .028$ ), suggesting that increased comfort with curricular material is modestly associated with greater instructional confidence.. Additionally, although most teachers participated in professional development activities (e.g., workshops, 81.4%), there was a demand for better resources, advanced laboratory equipment, and ongoing support.

Despite variations in teaching experiences, no significant differences between urban and rural teachers' responses were observed. The qualitative phase is necessary to validate these findings, understanding nuances and providing richer insights into how teachers navigate challenges, adapt strategies, and implement solutions in their classrooms. This dual approach ensures a solid understanding of the realities faced by biology teachers and addresses the limitations of each method.

### **Qualitative Phase**

The qualitative phase of this study involved semi-structured interviews with nine biology teachers in Kazakhstan. These participants were purposefully selected to provide

diverse perspectives from both urban and rural schools. This section presents the themes that emerged from the interviews, illustrating teachers' experiences, challenges, strategies, and support mechanisms related to teaching difficult biology concepts.

Thematic analysis, following Braun and Clarke's (2006) framework, was used to identify recurring patterns in the data. Five major themes emerged from the interviews: (a) the most difficult biology topics to teach, (b) strategies for overcoming the difficulties, (c) the role of resources and technology in teaching biology, (d) perceptions of professional development programs, and (e) recommendations for improving biology education.

### ***Participants' Demographic Information***

This section provides an overview of the demographic characteristics of the nine biology teachers who participated in the qualitative phase of the study. The participants were categorized into three experience levels: novice teachers with 0–5 years of experience (Group 1), experienced teachers with 5–15 years of experience (Group 2), and veteran teachers with 15+ years of experience (Group 3).

In terms of school location, five teachers worked in urban schools, while four teachers taught in rural schools. The participants' views on the current high school biology curriculum provided valuable insights into how contextual factors, such as access to resources, class sizes, and student preparedness, impact the teaching of difficult concepts. All participants reported moderate availability of digital resources, indicating they have the opportunity to request laboratory equipment and teaching materials at the beginning of the academic year.

A summary of the participants' demographics is presented in Table 10.

**Table 10**

### ***Demographics of Interview Participants***

Teacher №	Years of Experience	Type of School
-----------	---------------------	----------------

Teacher 1	2 years (Group 1)	Urban
Teacher 2	3 years (Group 1)	Urban
Teacher 3	1 year (Group 1)	Urban
Teacher 4	11 years (Group 2)	Urban
Teacher 5	13 years (Group 2)	Rural
Teacher 6	8 years (Group 2)	Rural
Teacher 7	29 years (Group 3)	Urban
Teacher 8	16 years (Group 3)	Rural
Teacher 9	23 years (Group 3)	Rural

### ***Theme 1: Most Difficult Biology Topics to Teach***

The analysis of interviews with biology teachers across different experience levels revealed that molecular biology, genetics, and photosynthesis are consistently mentioned as the most challenging topics to teach. Interviewees emphasized that the difficulty of teaching biology concepts varies across grade levels. Most teachers agreed that the 8th-grade biology curriculum is the most balanced, with the 9th-grade curriculum being nearly as well-structured. However, the 7th-grade curriculum was described as unbalanced and difficult to grasp, primarily due to the questionable order of topics and the requirement to cover a large amount of material within a 40–45-minute lesson.

The greatest difficulties were reported in the 10th and 11th grades, where the increased complexity of topics was further exacerbated by textbooks that were described as difficult to read and interpret. Teachers cited abstract concepts, student misconceptions, and inadequate resources as key barriers to effective instruction. However, the specific challenges varied based on teachers' experience levels, with novice teachers struggling more with conceptual explanations and student engagement, experienced teachers encountering student misconceptions and knowledge gaps, and veteran teachers highlighting the lack of updated resources and support materials.

**Novice teachers.** Novice teachers (Teachers 1-3) reported difficulties in conceptual explanations and maintaining student engagement when teaching cellular respiration, photosynthesis, molecular biology, and genetics. These topics require students to understand abstract processes, such as DNA replication, protein synthesis, and genetic inheritance, which are challenging to visualize. The absence of interactive resources and hands-on learning opportunities made it difficult for early-career teachers to bridge the gap between theory and practice.

One teacher highlighted the difficulty of explaining molecular processes without proper models:

“Explaining DNA replication to students without proper 3D models is nearly impossible” (Teacher 2, Online Interview, February 7, 2025).

Additionally, novice teachers noted that students often disengage when faced with complex biological topics due to their abstract nature. Photosynthesis, for example, was frequently mentioned as a topic that students struggle to grasp due to its biochemical complexity:

“Students hear about photosynthesis, but they don’t really understand how it works at the molecular level. It becomes just another term to memorize. Some of them just give up on learning the topic” (Teacher 1, Online Interview, January 31, 2025).

Some novice teachers suggested that digital simulations and animations could enhance student comprehension, but many schools, in their opinion, lack these resources (Teacher 3, Online Interview, February 8, 2024).

**Experienced Teachers.** Teachers with 5–15 years of experience (Interviews 4-6) highlighted student misconceptions and the curriculum inconsistency as primary

challenges. In particular, they criticized the 7th- and 10th-grade curricula for their lack of logical sequencing, noting that the order of topics does not align with the textbooks.

“Students often misunderstand photosynthesis; they mix it up with respiration, even after repeated explanations. We teach photosynthesis in plants first, then respiration separately, and later return to plant respiration, mixing it with animal and human respiration. This confuses students because they struggle to differentiate between processes occurring in different organisms.” (Teacher 4, Online Interview, January 25, 2025).

Another major issue was the integration of biochemistry into 10-11th grade high school biology curricula, which introduced additional complexity. Many experienced teachers noted that topics such as cellular respiration and molecular genetics require students to apply chemical principles that they may not yet fully grasp.

“The biggest challenge is that students don’t see the connection between chemistry and biology. They don’t understand how molecules interact in biochemical processes” (Teacher 5, Online Interview, February 4, 2025).

Additionally, experienced teachers expressed concern that the curriculum pacing does not allow enough time for in-depth explanations, forcing them to rush through complex concepts (Teacher 5, Online Interview, February 4, 2025).

**Veteran Teachers.** Veteran teachers (Interviews 7-9) emphasized the lack of updated resources and specific laboratory equipment as the primary obstacle when teaching complex biology topics. While they acknowledged that molecular biology and genetics are inherently difficult, they stressed that outdated textbooks with dense and academic language exacerbate these challenges.

“We have the opportunity to order proper lab equipment at the beginning of the school year, but due to the lack of guidance and experiment methodology, teachers have to prepare materials by themselves” (Teacher 7, Online Interview,

February 25, 2025).

Additionally, they criticized the overloaded curriculum, which introduces university-level topics without adequate instructional support:

“The 11th-grade curriculum includes topics that we studied in the first or second year of university. It’s too much for high school students” (Teacher 8, Online Interview, January 25, 2025).

Veteran teachers also favored the spiral curriculum, which revisits topics across multiple grade levels, and agreed it is a useful reinforcement tool. However, they noted that without updated textbooks and instructional materials, this approach loses its effectiveness (Teacher 9, Online Interview, January 31, 2025). Notably, novice teachers expressed skepticism about the spiral curriculum, believing the older linear curriculum was more comprehensible, despite not having taught it themselves (Teacher 1, Online Interview, January 31, 2025).

### ***Theme 2: Strategies for Overcoming Teaching Challenges***

Given the challenges identified in teaching difficult biology topics, teachers across all experience levels shared methods they employ to improve student understanding and engagement. These strategies included the use of digital tools, hands-on activities, and differentiated instruction. While novice teachers relied more on structured lesson planning and interactive resources, experienced and veteran teachers emphasized adaptive teaching methods, peer collaboration, and inquiry-based learning.

**Novice teachers.** Novice teachers (Interview 1-3) primarily focused on structured lesson planning and digital resources to compensate for the lack of visual materials in the textbooks. Many reported that using visual and interactive tools helped them explain abstract concepts more effectively.

“Since molecular biology concepts are too abstract for students to visualize, I

frequently use digital animations and online simulations to demonstrate processes like DNA replication and protein synthesis.” (Teacher 2, Online Interview, February 7, 2025).

To improve student engagement, novice teachers incorporated gamified learning and hands-on activities where possible. However, due to time constraints, they often relied on virtual experiments and classroom models rather than physical lab work.

“I use educational games and interactive quizzes to make difficult topics more engaging. Students tend to participate more actively when learning is structured as a game.” (Teacher 3, Online Interview, February 8, 2025).

Additionally, they structured lessons around real-world applications, group works, and discussion sessions to help students connect abstract biology topics to everyday life (Teacher 1, Online Interview, January 31, 2025).

**Experienced Teachers.** Teachers with 5–15 years of experience (Interviews 4-6) used differentiated instruction and inquiry-based learning to address student misconceptions and curriculum inconsistencies. Many emphasized the need to break down complex topics into smaller, digestible units and use scaffolding techniques to guide student learning.

“When teaching photosynthesis and respiration, I introduce simplified models and illustrations first and then gradually add complexity. I find them on the internet, adapt them for our lessons. This prevents students from getting overwhelmed by too much information at once.” (Teacher 4, Online Interview, January 25, 2025).

Many experienced teachers also used peer collaboration and group projects to reinforce learning. They noted that student-led discussions, debates, and collaborative assignments helped clarify difficult concepts:

“I assign small groups to research different aspects of a topic and present their findings. This encourages peer teaching and deepens understanding.” (Teacher 5, personal communication, February 4, 2025).

**Veteran Teachers.** Veteran teachers (Interviews 7-9) emphasized adaptive teaching methods, hands-on experiments, and real-world applications as the most effective strategies for overcoming instructional challenges. Given their extensive classroom experience, they were more likely to develop customized instructional materials and adapt lessons to different student needs.

“I have developed my own simplified models and diagrams to explain complex topics. The textbooks are too dense, so I create custom resources and presentations that focus on the key points students need to understand.” (Teacher 8, Online Interview, January 25, 2025).

Many veteran teachers also found practical demonstrations and project-based learning particularly effective, even in resource-limited settings. Despite the lack of lab equipment, they improvised experiments using household items or sought alternative resources:

“We may not have access to a full laboratory, but we find ways to demonstrate key concepts. For example, to show osmosis, we use simple materials like potatoes and saltwater.” (Teacher 9, Online Interview, January 31, 2025).

Veteran teachers also supported interdisciplinary approaches, integrating environmental science, medicine, and biotechnology into lessons to increase student engagement.

“I link biology to real-world applications—medicine, environmental issues, and current research—so students see its relevance beyond the classroom.” (Teacher 7, Online Interview, January 25, 2025).

Another effective strategy used by veteran teachers was mentoring younger teachers, sharing best practices, and providing informal professional development opportunities:

“New teachers often struggle with curriculum pacing and classroom management. I mentor them by sharing lesson plans, classroom strategies, and teaching resources.” (Teacher 7, Online Interview, January 31, 2025).

### ***Theme 3: The Role of Resources and Technology in Teaching Biology***

Teachers highlighted how resources and technology shape their ability to teach biology effectively, though access and preferences varied widely. While some educators benefited from modern labs and digital tools, others faced challenges like outdated materials, insufficient technical training, and a lack of support staff. Reliance on interactive tools also differed by experience: novices leaned on digital platforms, experienced teachers blended traditional and modern methods, and veterans emphasized funding and methodological support for hands-on learning.

**Novice teachers.** For novice educators, technology bridged gaps in lab access and classroom experience. Tools like interactive whiteboards, animations, and virtual labs were critical for teaching molecular biology and genetics.

“When lab experiments aren’t available, animations and virtual labs let me show processes like osmosis or cell division. It’s not perfect, but it works. What makes it complex is that they are all in English, I compensate for it with my own explanation” (Teacher 2, Online Interview, February 6, 2025).

A growing trend among novice teachers was the adoption of AI-powered tools for tasks like lesson planning and resource creation. Many used these tools to generate quizzes, simulations, and tailored materials, streamlining their workload.

“AI helps me design better lessons and customize resources for students. I can

create interactive worksheets or target quizzes for their weak spots in minutes” (Teacher 3, Online Interview, February 7, 2025).

Additionally, some novice teachers struggled with technical barriers such as limited internet access, software restrictions, and the high cost of digital resources.

**Experienced teachers.** For experienced teachers, laboratory experiments remained the most valuable resource, with digital tools serving as supplements rather than replacements. Teachers noted that students preferred hands-on experiences, as they enhanced engagement and understanding of abstract topics.

“Children love laboratory work, especially when they get to do it themselves—working with microscopes, examining samples. It makes a huge difference in their learning.” (Teacher 4, Online Interview, January 25, 2025).

Additionally, some experienced teachers found that students' initial enthusiasm for digital tools declined over time as they became accustomed to them

“We didn't have this interactive panel in the classroom before. The first year, students were very excited, but now they are used to it. It has just become another tool.” (Teacher 5, Online Interview, February 4, 2025).

However, even in equipped schools, teachers faced challenges related to resource shortages and lack of support staff:

“Even though my lab is fully equipped, I still have to buy a lot of materials on my own, and I don't have a lab assistant. It's exhausting.” (Teacher 6, Online Interview, February 5, 2025).

Another major concern was the gradual decline in student interest when using the same teaching methods repeatedly. Teachers found that varying instructional approaches, such as combining digital tools, experiments, and discussion-based learning, kept students engaged (Teacher 5, Online Interview, February 4, 2025).

**Veteran teachers.** Veteran teachers pointed out the inadequacy of educational resources and lack of adaptations with updated curriculum. Many highlighted the need for updated textbooks and professional training to use digital tools effectively.

“We are expected to integrate technology, but specific training with examples is rarely provided. Many teachers have to figure it out on their own.” (Teacher 7, Online Interview, January 25, 2025).

While considering the usefulness of digital resources, veteran teachers emphasized that hands-on learning through experiments was irreplaceable.

“Virtual labs are useful, but they don’t provide the tactile experience students need. A student who performs an actual experiment retains much more than one who just watches an animation.” (Teacher 9, Online Interview, January 31, 2025).

Additionally, veteran teachers shared their opinion on the spiral learning curriculum in Kazakhstani high school biology, emphasizing the importance of reinforcement learning and the need to improve the textbooks according to the goals of spiral learning theory.

“I personally love the new spiral system of learning. Children have the opportunity to repeat the topics over the course of 5 years and add more advanced knowledge on each topic. However, the implementation through resources, mainly the textbooks, must be revised, as the 11th grade biology book, for example, is incredibly hard to understand for teachers, let alone students.” (Teacher 7, Online Interview, January 25, 2025).

#### ***Theme 4: Professional Development and Support for Biology Teachers***

Professional development (PD) and institutional support proved critical in addressing instructional challenges, according to teachers across all experience levels. Teachers emphasized the need for practical training, improved mentorship, and better

alignment between PD programs and classroom realities. However, they also pointed out significant gaps in PD accessibility, effectiveness, and implementation.

**Novice teachers.** Novice educators leaned heavily on PD to strengthen their content knowledge and teaching strategies. However, many criticized programs for prioritizing theoretical frameworks over practical classroom applications.

“Most courses I took focused on general pedagogy, not how to break down complex biology concepts” (Teacher 3, Online Interview, February 8, 2025).

Structured mentorship emerged as a recurring need. While novice teachers often lacked formal mentorship programs, some highlighted the value of informal guidance from experienced colleagues.

“Experienced teachers share teaching methods with me, and I show them new digital tools. The support from colleagues and the administration has been crucial as a new teacher” (Teacher 1, Online Interview, January 31, 2025).

**Experienced teachers.** For experienced teachers, the main challenge with PD programs was that they often did not provide training on advanced biology topics. Many teachers found existing training programs repetitive, covering basic teaching methodologies rather than cutting-edge developments in biotechnology, genetics, and molecular biology.

“I do not think the biology we teach in schools is keeping up with scientific discoveries. Train us on current research, so we can teach real-world applications of knowledge.” (Teacher 6, Online Interview, February 5, 2025).

Additionally, some experienced teachers expressed frustration with the scheduling of PD programs, noting that training often takes place at inconvenient times, such as at the beginning of the academic year when workload is already high.

“The worst time for PD is August-September when we are drowning in lesson

planning and reporting. Training sessions should be scheduled when we actually have time to absorb and apply the information.” (Teacher 5, Online Interview, February 4, 2025).

**Veteran teachers.** Veteran teachers were the most critical of the current PD structure, arguing that the majority of training programs were ineffective, redundant, and disconnected from classroom realities. They expressed frustration with theory-based courses that did not provide concrete, actionable strategies for improving instruction.

“We don’t need another general teaching workshop. We need expert-led discussions where experienced teachers share what actually works in the classroom.” (Teacher 8, Online Interview, January 25, 2025).

Another key issue raised by veteran teachers was the lack of funding for professional growth. Many had to pay for advanced training out of pocket if they wanted to stay updated with new scientific developments in biology.

“If I want to attend an international training on biotechnology or advanced lab techniques, I have to pay for it myself. There’s no financial support for ongoing professional development.” (Teacher 8, Online Interview, January 25, 2025).

On the other hand, some veteran teachers also noted that rural educators face less limitations in PD access compared to previous years.

“Rural schools have access to digital resources. Some training sessions are conducted in district centers, while others take place in regional centers. I do not find this to be a huge obstacle for me.” (Teacher 9, Online Interview, January 31, 2025).

Additionally, some veteran teachers took initiative by informally mentoring younger colleagues, sharing best practices and lesson planning strategies.

“New teachers often struggle with curriculum pacing and classroom management. I mentor them by sharing lesson plans, classroom strategies, and

teaching resources.” (Teacher 7, Online Interview, January 25, 2025).

### ***Recommendations for Improving Biology Education***

The final theme emerging from the interviews focuses on teachers' recommendations for improving biology education in Kazakhstan. Teachers across all experience levels shared insights on curriculum adjustments, resource allocation, professional development improvements, and student engagement strategies. Their recommendations reflect the need for systemic changes to enhance the effectiveness of biology instruction and better support both educators and students.

**Novice teachers.** Novice teachers emphasized the need for more structured support, particularly in curriculum pacing, access to high-quality teaching resources, and mentorship programs. They often struggled with covering complex topics within limited lesson time, making it difficult to ensure student comprehension.

“We need more time to explain difficult topics. The curriculum moves too fast, and students don't have enough time to fully grasp concepts like molecular biology and genetics.” (Teacher 2, Online Interview, February 6, 2025).

A major recommendation from novice teachers was the expansion of AI-powered tools for lesson planning, content creation, and assessment preparation. While some were already using AI for generating quizzes and study materials, they suggested developing official AI-assisted platforms tailored to the Kazakhstani curriculum.

“AI tools have helped me a lot in creating lesson plans and materials, but it would be great to have an official platform designed specifically for our curriculum and language of instruction.” (Teacher 3, Online Interview, February 8, 2025).

They also requested stronger mentorship programs that would connect early-career teachers with experienced educators for guidance and support.

“Having a mentor would make a significant difference. Right now, we’re mostly figuring things out on our own.” (Teacher 1, Online Interview, January 31, 2025).

Additionally, some novice teachers shared their view on current high school biology textbook materials.

“I wish the textbooks would be written and reviewed by a big number of experienced and veteran biology teachers. Right now, I feel like the 7th grade biology textbook is written and edited by a university professor. The translation from Russian to Kazakh is also questionable to me, as it leaves out a huge amount of material and has even denser style” (Teacher 1, Online Interview, January 31, 2025).

**Experienced Teachers.** For experienced teachers, recommendations focused on curriculum restructuring, improved laboratory access, and more practical professional development. Many noted that students learn best through hands-on experiments, yet resource shortages and limited lab time often prevented them from conducting practical lessons

“Students understand concepts much better when they conduct experiments. We need better lab facilities and access to consumable resources, especially in rural schools.” (Teacher 6, Online Interview, February 5, 2025).

Another major concern was curriculum coherence—teachers found that some topics were introduced too early, leading to confusion among students. They suggested restructuring topic sequencing to ensure better comprehension.

“Some topics, like genetic inheritance in 9th grade, should be introduced later, when students have a stronger foundational knowledge. Right now, they struggle with concepts that are too advanced for their level. For example, I have to teach epistasis and polymery while they can not distinguish between

dominant and recessive traits.” (Teacher 4, Online Interview, January 25, 2025).

“I find the 10th-grade biology textbook well-structured, but the 11th-grade textbook needs a serious update. Some topics seem to be included just because they are trending, yet they lack the necessary depth and contain more narrative than substantial scientific content” (Teacher 5, Online Interview, January 31, 2025).

**Veteran Teachers.** Veteran teachers emphasized long-term improvements in teacher workload, funding for professional growth, and increased autonomy in curriculum implementation. Many felt that excessive administrative duties took away from lesson planning and student engagement

"We spend so much time on paperwork and reports. If we had fewer administrative burdens, we could focus more on teaching and student support. Furthermore, most of the current PD programs are focused on lesson planning paperwork, not on the methodology which can be utilized in the classroom" (Teacher 8, Online Interview, January 25, 2025).

Another pressing concern was funding for lab equipment and teacher training. Veteran educators suggested establishing government-funded grants for schools to upgrade their biology laboratories.

"If schools received annual funding specifically for consumable experimental materials, students would get much better hands-on learning experiences. Additional guidelines on experiments for the high school biology curriculum would be useful." (Teacher 9, Online Interview, January 31, 2025).

Veteran teachers also emphasized the need for greater flexibility in curriculum implementation, allowing teachers to adjust lesson pacing based on student comprehension rather than rigid schedules.

"We should have more autonomy to slow down and revisit difficult topics

instead of rushing through the curriculum just to meet deadlines." (Teacher 7, Online Interview, January 25, 2025).

Additionally, some veteran teachers advocated for formal training on AI-assisted teaching. While younger teachers were already using AI tools for lesson planning, some older educators found it challenging to integrate AI into their workflow.

"I see young teachers using AI for lesson planning, and it looks helpful. If we had proper training on AI tools, it could make our job easier too." (Teacher 7, Online Interview, January 25, 2025).

### ***Qualitative Phase Summary***

The qualitative phase revealed key challenges biology teachers face in delivering complex topics such as molecular biology, genetics, and photosynthesis. Educators identified inconsistencies in the curriculum, persistent student misconceptions, and unequal resource access as primary barriers. To address these, teachers employed strategies like digital simulations, hands-on learning, and interdisciplinary connections, though their effectiveness varied due to uneven resource distribution and insufficient professional development.

Notably, recommendations centered on three areas: restructuring the curriculum to align with student readiness, increasing funding for lab infrastructure, and granting teachers greater autonomy to adapt pacing. While novices emphasized AI-driven tools for lesson planning, experienced and veteran teachers advocated for hands-on experimentation and targeted professional training. Collectively, these findings underscore the urgency of system-level changes to address disparities in resources, training, and curricular flexibility, ultimately strengthening biology education across Kazakhstan.

## **Chapter 5: Discussion**

The aim of this chapter is to combine both quantitative and qualitative data to provide a summary of the challenges and strategies reported by biology teachers in Kazakhstan. The research investigates the difficulties of teaching complex topics by linking these results to existing theories about teacher self-efficacy and agency. The research reveals that resource constraints in combination with PD content and curriculum issues are primary factors which influence teaching practices and show the strategies educators use to address these barriers.

Additionally, the chapter addresses the study's limitations, such as dependence on self-reported data and cross-sectional research design, while presenting recommendations for future studies that focus on PD improvement and resource allocation. Overall, the discussion not only responds to the research questions but also delivers useful recommendations to improve biology education within Kazakhstan's secondary school settings.

### **Influence of Resource Adequacy, Professional Development, and Curriculum**

#### **Comfort on Teachers' Confidence**

This section attempts to answer the first research question about the impact of resource adequacy, professional development (PD) participation and comfort with curriculum on biology teachers' confidence in teaching complex concepts. The analysis of survey data and interview results is done to study these relationships and their impact on teachers' self-assurance in the classroom. The research applies Bandura's Self-Efficacy Theory to evaluate how these factors either strengthen or weaken teachers' confidence in managing difficult biology material.

#### ***Quantitative Findings***

The survey findings demonstrated that teachers who felt comfortable with the

curriculum also demonstrated higher confidence in teaching complex biology concepts. Given the ordinal data from Likert-scale responses, Spearman's rank correlation analysis was used to determine this relationship. Teachers who demonstrated better comfort with the current curriculum showed higher confidence levels according to the analysis which produced a modest positive correlation,  $\rho = 0.23$ ,  $p = .028$ . The results indicate that teachers' comfort level with the planned material directly influences their confidence levels.

The survey results demonstrated that resource adequacy emerged as a critical factor for success. Laboratory equipment shortages emerged as a significant teaching challenge according to 62.5% of teachers who identified this issue as a major barrier. The majority of teachers (81.4%) participated in professional development workshops or seminars during the previous year. These findings highlight the importance of adequate resources and continuous PD in supporting effective biology instruction.

### ***Qualitative Findings***

The interviews expanded the quantitative results to show how lack of resources affects teachers in distinct ways based on their years of experience. Novice teachers, in particular, voiced significant challenges. A beginner teacher stated, "Explaining DNA replication without proper 3D models is nearly impossible" (Teacher 2, personal communication, February 7, 2025). This frustration reveals that limited resources make teaching complex abstract topics more difficult, leading to declining self-assurance among teachers, especially those in their early stages of teaching.

The more experienced instructors demonstrated better resilience in their responses. One experienced teacher explained, "I've used potatoes to show osmosis when there's no lab equipment—it's not ideal, but it works" (Teacher 9, personal communication, January 31, 2025). While this adaptability reflects years of problem-solving, it also exposes an over-reliance on individual creativity instead of

proper systemic support which appeared throughout the interview results.

### ***Theoretical Connection***

Bandura's (1977) Self-Efficacy Theory provides a framework for understanding these dynamics. The theory's four sources of self-efficacy—mastery experiences, vicarious experiences, social persuasion, and physiological/emotional states help to explain the dynamics of teacher confidence in Kazakhstan's reform-driven context.

**Mastery Experiences:** Successful teaching, such as conducting experiments, builds self-efficacy. However, 62.5% of teachers reported laboratory equipment shortages, limiting practical lessons (Table 3). Novice teachers, like Teacher 2, struggled, stating, "Explaining DNA replication without 3D models is nearly impossible" (Teacher 2, February 7, 2025), reducing mastery opportunities and confidence. Experienced teachers, such as Teacher 9 using potatoes for osmosis, rely on past successes to sustain confidence despite constraints (Teacher 9, January 31, 2025).

**Vicarious Experiences:** Observing peers fosters self-efficacy, but PD workshops (81.4% participation, Table 7) often lack topic-specific content, like biotechnology, limiting relevant models (Teacher 6, February 5, 2025). Novices miss practical strategies, while experienced teachers gain from informal peer networks, such as Teacher 7's mentoring (Teacher 7, January 25, 2025).

**Social Persuasion:** Encouragement from colleagues or PD facilitators boosts confidence, but resource gaps and administrative demands weaken this. Novices feel unsupported with the complex 11th-grade curriculum (Teacher 1, January 31, 2025), and experienced teachers note excessive paperwork hinders support (Teacher 8, January 25, 2025).

**Physiological/Emotional States:** Curriculum discomfort (Spearman's  $\rho = 0.23$ ,  $p = .028$ ) induces stress, eroding self-efficacy, especially for novices teaching abstract

topics like photosynthesis (Teacher 1, January 31, 2025). Comfortable teachers, particularly with 8th-grade curricula, report positive emotions, enhancing confidence (Teacher 4, January 25, 2025).

Bandura's framework shows that resource shortages limit mastery and vicarious experiences, especially for novices, while curriculum discomfort leads to stress. PD's generic nature limits relevant learning, though experienced teachers leverage on mastery and connections. Targeted resources and training are critical to bolster self-efficacy across all teachers, especially novices, in Kazakhstan's biology classrooms.

### ***Interpretation***

These findings echo broader research on STEM education. According to Tekkaya et al. (2001), laboratory resources form an essential component for building teacher efficacy in biology which this study confirms. Resource disparities between rural and urban areas in Kazakhstan intensify these problems as reported by Akhmetova and Murzalinova (2018). Many regions of Kazakhstan face STEM reform expansion which exceeds their infrastructure development making it difficult for teachers to teach with insufficient resources (McLaughlin et al., 2023).

The combination of resource restrictions with curriculum requirements and professional development training produces complex effects on teacher confidence. Novice teachers experience weakened confidence due to inadequate resources and challenging curriculum demands that create difficulties for their future teaching careers. The experienced teachers manage better through their expertise but the 11th-grade curriculum's difficulty continues to present obstacles. The lack of sufficient topic-specific content in professional development programs was reported by teachers who frequently participated in workshops but still faced knowledge gaps especially in biotechnology.

Resource availability along with tailored professional development proves essential for teachers while curriculum comfort stands as the leading indicator of confidence. The development of solutions to these educational system problems would enable Kazakhstani biology teachers to accomplish evolving curriculum goals with enhanced certainty.

### **Teachers' Perceptions of Support and Professional Development**

This section presents how biology teachers in Kazakhstan perceive professional development (PD) and support, addressing the second research question. By blending survey numbers with teachers' own words, a clear sense of what's working, what's not, and how well these efforts prepare them for a curriculum that's pushing new boundaries is revealed. Kennedy's (2005) Professional Development Model is used to frame the discussion, while connections to global research and Kazakhstan's unique challenges sharpen the analysis.

#### ***Quantitative Findings***

Survey data includes statistics on how teachers perceive professional development and support. These results indicate that a majority, 51.8%, of the teachers found the PD to be "very useful" in enhancing their ability to teach challenging biology concepts, thus suggesting that most of them found these programs useful. Nevertheless, this positive finding is somewhat offset by other responses: 45.9% of teachers stated that they needed more PD, implying that there is a perceived deficit in the frequency or scope of PD. Moreover, 57.6% of the teachers indicated that they wanted more teaching resources such as modern textbooks and digital tools, which points to a deficit that goes beyond PD itself.

These numbers represent a partial satisfaction. More than half of the teachers have a positive perception of PD, while almost the same number feel that it does not go far enough, and the majority mention resource limitations as a barrier. This duality

suggests that, although PD offers some benefits, it may not fully prepare teachers for the complexities of the current curriculum, especially in resource limited settings.

### ***Qualitative Findings***

Teacher interviews add depth to these statistics, and it is possible to distinguish between the perceptions of different categories of teachers. Novice teachers emphasized the need for PD that would connect theory to practice in biology specific concepts. “Most courses focused on pedagogy, not biology concepts” said one early-career teacher (Teacher 3, personal communication, February 8, 2025). This point shows that what is needed is training that is focused on the subject matter that teachers are teaching as opposed to broad teaching techniques.

In contrast, experienced teachers expressed an idea for advanced content to be able to compete with scientific progress. “Train us on current research, so we can teach real world applications of knowledge” said one mid-career educator (Teacher 6, personal communication, February 5, 2025). This desire is in tune with the new curriculum that focuses on topics like biotechnology that typically require more than general knowledge.

Veteran teachers, however, were the most vocal critics, often complaining that PD is repetitive or irrelevant to their experience. A long-serving teacher put it thus, “We need expert-led discussions where experienced teachers share what actually works in the classroom” (Teacher 8, personal communication, January 25, 2025). This plea for practical, peer driven learning indicates that the current forms of PD, which are often standardized and lecture based, fail to tap into the expertise that these teachers bring.

### ***Theoretical Connection***

Kennedy’s (2005) framework for professional development (PD) is useful to understand biology teachers’ experiences in Kazakhstan, dividing PD into three

approaches: transmission, transitional, and transformative. By applying these concepts, it becomes clear why the current PD system, heavily focused on workshops, supports teachers to some extent but struggles to meet their diverse needs in a demanding curriculum.

Transmission PD, where workshops deliver fixed content, is common, with 81.4% of teachers attending such sessions (Table 7). Many (51.8%) found these “very useful” (Table 8), yet novice teachers like Teacher 3 expressed frustration: “Workshops teach general teaching methods, not how to explain biology topics” (personal communication, February 8, 2025). This gap shows that transmission PD offers basic tools but often misses the mark for teaching complex subjects like biotechnology.

Transitional PD blends content delivery with collaboration, such as peer observations (46.5% participation, Table 7). Experienced teachers, like Teacher 6, want more: “We need training on recent scientific discoveries to connect lessons to real life” (personal communication, February 5, 2025). While transitional PD could help, its limited use means teachers miss opportunities to adapt new ideas to their classrooms.

Transformative PD, rooted in ongoing collaboration like mentoring or teacher communities, better suits teachers’ calls for tailored support. Veteran Teacher 8 urged for “discussions where we share practical strategies” (personal communication, January 25, 2025), while novices like Teacher 1 sought mentorship to apply theory practically (personal communication, January 31, 2025). With 45.9% of teachers wanting more PD, the absence of transformative approaches leaves a gap in fostering long-term growth.

Kennedy’s model highlights a key issue: Kazakhstan’s PD leans on transmission methods, while teachers crave transitional and transformative support to meet varied needs—practical guidance for novices, cutting-edge content for experienced educators, and peer learning for veterans. This mismatch, worsened by

resource shortages, limits teachers' ability to innovate, echoing Priestley et al.'s (2015) view that agency depends on strong support systems.

### *Interpretation*

The results are consistent with the trends observed in the global science education literature. According to Elster (2009) and Rozenszajn and Yarden (2014), effective PD for science teachers is one that combines content knowledge with teaching techniques, supported by continuous, rather than intermittent, practice. However, local studies such as Zharylkassyn (2023) indicate that there are still gaps, including an urban bias in PD provision that leaves rural teachers behind—a concern that was raised by some of the interviewees when they talked about travel and resource barriers. The collected data demonstrates that the professional development offered does not match the actual support needs of teachers to address the new curriculum's difficulties. The workshop-based PD receives positive feedback but typically fails to provide teachers with the detailed and specific instruction they need to teach complex biology material effectively. The lack of specific practical guidance for novices combined with advanced content needs of experienced teachers and relevant professional development needs of veterans indicates that better customized transformative PD is necessary.

The demand for better resources emerged as a key concern from 57.6% of teachers. The effectiveness of any PD program will be diminished by the absence of essential resources including updated educational materials and technological tools especially when the curriculum focuses on real-world applications. The relationship between professional and material support reveals an extensive systemic issue affecting biology education in Kazakhstan.

The gap between educational requirements and teaching practices restricts teacher self-direction and their capacity to introduce classroom innovations. The study by Priestley et al. (2015) indicates that teacher agency grows when educators receive

adequate resources and autonomy yet teachers in this setting face restricted curriculum response capabilities because of insufficient PD and limited resources. Biology teachers in Kazakhstan need to address this educational gap because it will enable them to develop professionally and establish successful curriculum implementation.

### **Strategies and Resources Used to Teach Difficult Biology Concepts**

This section addresses Research Question 3 of the study which focuses on the strategies and resources that biology teachers in senior secondary schools in Kazakhstan apply in teaching complex concepts. This discussion examines the ways in which they approach their work, evaluates their effectiveness, and relates them to best practices and teacher agency in order to understand the actual practice of biology education in Kazakhstan. The analysis is based on survey data from 113 teachers and interview data from nine participants, analyzed using Priestley's Teacher Agency Framework (Priestley et al., 2015) and connected to the international literature on science education research.

#### ***Quantitative Findings***

According to the survey, the most commonly used resources in teaching challenging biology subjects include online videos or tutorials with 80.6% of the respondents agreeing with the statement, followed by textbooks with 72.0%. These are accessible and relatively low-cost options, which are practical to the classroom needs. However, more resource intensive strategies were found to be less popular as only 45.2% of teachers employed laboratory experiments and 44.1% used digital simulations or virtual labs. This may be due to the fact that there is inadequate provision of equipment and technology, which means that teachers have to rely on what they have rather than on what would be best for active or interactive learning.

#### ***Qualitative Findings***

The interviews with teachers of different experience levels provide additional

insights into their strategies, showing both the creativity and the constraints they face.

**Novice Teachers:** In general, novice teachers tend to use different digital resources to fill in the gaps. One novice teacher said, “I use animations for DNA replication, that is the best I can do without a lab” (Teacher 2, Personal communication, February 6, 2025). This reliance on visuals can make genetics tangible to comprehend as a concept, although it also reveals a dependence on technology to compensate for limited hands-on opportunities.

**Experienced Teachers** prefer scaffolding to help students navigate through complexity. One teacher said, “I begin with simple models and then add more details, students explain everything themselves” (Teacher 4, Personal communication, January 25, 2025). This step-by-step approach is a clear attempt to enhance learning, and is consistent with the authors’ pedagogical knowledge to tackle difficult topics such as cellular processes.

**Veteran Teachers** are notable for their creativity. One veteran said, “We use potatoes for osmosis” (Teacher 9, Personal communication, January 31, 2025), showing how they make the most of things they have to use as teaching aids. This improvisation is indicative of their adaptability, but it also reveals the lack of systemic support for constant, active learning.

### ***Theoretical Connection***

Priestley et al. 's (2015) Teacher Agency Framework illuminates how biology teachers in Kazakhstan teach complex concepts, viewing agency through iterative, practical-evaluative, and projective dimensions shaped by personal capacity and structural factors. This lens reveals teachers' strategic choices amid resource constraints.

The iterative dimension draws on past experience. Veteran Teacher 9, using potatoes for osmosis, leverages years of improvisation (personal communication,

January 31, 2025), but limited lab access (45.2% usage, Table 9) restricts such creativity. Practical-evaluative agency involves real-time decisions. Experienced Teacher 4 scaffolds cellular processes, starting simply (personal communication, January 25, 2025), yet scarce digital tools (44.1% simulation use, Table 9) curb options. The projective dimension reflects future goals. Novice Teacher 2 uses animations for DNA replication (personal communication, February 6, 2025), relying heavily on videos (80.6%, Table 9) due to limited training.

Priestley's framework shows novices' pragmatic but shallow agency, experienced teachers' strategic scaffolding, and veterans' adaptive creativity, all constrained by structural barriers like resource scarcity. Agency requires better support to shift from reactive to innovative teaching in Kazakhstan.

### ***Interpretation***

Research in science education from around the world offers a comparison. Virtual labs, which Zulyusri et al. (2023) lauded for improving understanding in low resource settings, align with novices' reliance on digital tools, though Kazakhstan's modest 44.1% adoption rate reveals infrastructure challenges noted by Ilma et al. (2020). Problem-based learning, which McLure et al. (2022) recommend for developing critical thinking, is hardly used (5.4%), likely because of similar constraints. While some best practices used by teachers in Kazakhstan are creative, the over-reliance on videos and textbooks diverges from the trends in inquiry-driven learning and calls for broader access to innovative resources.

These instructional methods produce varying effectiveness levels. Digital tools preferred by novices provide clear and engaging content but they generally fail to deliver sufficient depth to analyze complicated subjects like molecular biology. The experienced teacher uses scaffolding to develop student understanding although this method needs substantial preparation time which may not always be feasible. The

success of potato-based osmosis demonstrations by veterans depends on individual student dedication as well as available materials yet these methods remain challenging to expand.

Learning outcomes could reach their highest potential by using a combination of digital tools with scaffolding techniques along with hands-on educational activities. Teachers face ongoing obstacles because systemic improvements such as lab equipment and reliable technology and targeted training do not exist. A fundamental barrier exists which restricts teacher impact because we need to support both teacher independence and structural development for biology education advancement in Kazakhstan.

### **Implications for Biology Education in Kazakhstan**

This section connects the study's results to offer specific and broad recommendations for biology education in Kazakhstan and other countries. Therefore, it proposes measures to address systemic challenges, empower teachers, and ensure that recommendations are in line with the country's STEM agenda to enhance the teaching of biology in secondary schools.

#### ***Systemic Challenges***

The study identified numerous problems affecting biology education. An issue of concern is the overloaded curriculum especially at the 11th grade level where teachers are expected to cover topics that are more relevant to university lectures than high school classes. One teacher was very direct in his observation and stated, "The 11th grade curriculum is made up of topics that we covered in university, it is too complex for high school students" (Teacher 8, personal communication, January 25, 2025). This is compounded by resource inequality as urban schools have better laboratories than rural schools. Although professional development (PD) is provided to teachers, it is usually general teaching approaches that are emphasized, and not the

specific STEM oriented approaches as recommended in Order No. 399 (Ministry of Enlightenment, 2022).

### ***Teachers' Recommendations***

Teachers are not only aware of the challenges they face, but they are also coming up with possible solutions. An experienced biology teacher suggested rearranging the curriculum for better continuity: “Genetic inheritance in 9th grade is too early—students need a good background first” (Teacher 4, personal communication, January 25, 2025). Another teacher who has many years of experience in teaching advocated for more lab funding and had a vision of “annual grants for consumable materials to enhance the practical work” (Teacher 9, personal communication, January 31, 2025). However, a young teacher perceived the use of AI tools as a possibility to reduce the burden of preparing lessons but noted that there is a need for accessible platforms (Teacher 3, personal communication, February 8, 2025). These are good ideas, but they are not without their difficulties—grants require financial stability, and AI calls for infrastructure and people to train.

### ***Contextual Relevance***

The STEM reforms in Kazakhstan that have been initiated through the Order No. 399 (Ministry of Enlightenment, 2022) seek to produce critical thinkers and practicable individuals. But the study reveals a problem: the current challenges, such as limited resources and an overcrowded curriculum, are not consistent with these ambitions. This could increase the gap between urban and rural students, a threat identified by Zhumabay et al. (2024). Without addressing the problems, the effort to provide equitable, high-quality biology education will fail.

### ***Policy and Practice***

There are three main actions that can be taken to change the negatives into positives:

Increased Guidance for Resource Allocation: Fund lab grants and textbook resource improvement to provide opportunities for all students to have practical experience.

Redesign PD for Transformative Learning: Go beyond the one-off workshops and create ongoing biology focused mentoring and communities that really make a difference.

Curriculum Pacing and Sequencing: Reduce the content load and reorganize topics to build up students' knowledge in a step by step fashion and not all at once.

These shifts could improve teachers' confidence and flexibility—key drivers of reform success, as Bandura's (1977) self-efficacy theory and Priestley et al.'s (2015) agency theory suggest. When teachers are well-prepared and motivated, students excel.

## **Chapter 6: Conclusion**

The study aims to determine the challenges faced by biology teachers in Kazakhstan in teaching complex topics to senior secondary level students based on the effects of resource availability, professional development, and curriculum relevance on teacher confidence, perceived support and strategies used in teaching. It used a mixed methods approach with survey data from 113 teachers and interview data from nine teachers in novice, experienced, and veteran categories to tell a story of resilience within the context of systemic challenges that could inform Kazakhstan's STEM education reforms.

### **Restatement of the Research Problem and Objectives**

This research was aimed to establish the difficulties that biology teachers face when teaching topics such as molecular biology and genetics, and to assess their readiness to teach based on the resources, training and curriculum familiarity. It also analyzed their perceptions of support systems and the actual strategies used in practice. The study used a combination of quantitative and qualitative data to present a comprehensive view of biology education in Kazakhstan and recommend potential solutions.

### **Summary of Key Findings**

Quantitatively, there was a clear association between teachers' comfort with the curriculum and their confidence, with many indicating that they were more comfortable with the material when teaching difficult concepts. Lack of resources was a common concern, as 62.5% of teachers identified lab equipment as a constraint; while professional development, which was attended by 81.4% of the sample, was generally unsatisfactory. Interviews provided more insight: beginners had problems with abstraction and lacked tools; they used digital resources; experienced teachers helped students overcome their mistakes; and veteran teachers came up with creative

solutions, such as using potatoes to explain osmosis, despite the lack of resources. This was evident at all the levels of study, and the results showed that curriculum overload, especially in grade 11, and lack of support highlighted a system that is under pressure.

### **Implications and Theoretical Contributions**

These findings have implications for the education system in Kazakhstan. In practical terms, schools require better lab facilities, especially in rural areas, to create equity. Professional development should move away from the current generic workshops and be more specific, sustained and focused on advanced biology and classroom practice. Curriculum pacing needs to be reviewed, and perhaps topics can be sequenced in a more gradual manner to correspond to student readiness. These steps are in line with national STEM goals (Ministry of Enlightenment, 2022), which are expected to enhance teacher self-efficacy and student achievement if supported by sustained financing.

Theoretically, the study supports Bandura's (1977) self-efficacy theory, which states that confidence increases with mastery and resources, and Priestley et al.'s (2015) agency framework, which illustrates how teachers can work around the system. This thesis work builds on these ideas by arguing that resource shortages create systemic gaps that restrict agency, and therefore, teachers cannot be empowered without structural support.

### **Limitations and Future Research Directions**

No study is without flaws. The cross-sectional design gave a snapshot of a particular moment in time, rather than showing how things change over time, and the self-report data may be biased—teachers may have exaggerated their challenges or minimized their achievements. The small qualitative sample of nine, although very rich in detail, cannot be generalized to all the participants. These limitations make the findings a good starting point, rather than the last word, and therefore should be treated

with caution.

Future work could involve longitudinal studies that follow the impact of changes in resources or redesigned professional development on teaching. Testing interventions—such as AI tools for novices or lab grants for rural schools—provides an opportunity to measure actual change. A comparison of Kazakhstan's approach with other global models, for example, Finland (Elster, 2009), might provide some adaptable strategies. These paths could help improve the plan this study has proposed.

### **Reflective Closing**

When considering this work it is evident that Kazakhstan's biology teachers are a hardworking group of people who have incorporated digital resources, practical solutions, and pure perseverance into their teaching. However, their hard work takes place in a context of variable support – and the idea that talent alone cannot solve all the problems. This study provides a grounded voice to the STEM reform debate, shedding light on teachers' challenges and possible solutions. It is not just an academic exercise; it is a call to action, with the aim of igniting curiosity and change for a system that is set to grow. As Kazakhstan moves towards a knowledge-based economy, supporting these educators could convert difficulties into opportunities, making biology classes more exciting for many years to come.

## References

- Adejimi, S., Shivoga, W., & Nzabwirwa, W. (2023). Using consensus and cooperative reflective journal writing instructional strategies to enhance students' achievement in Biology. *Interdisciplinary Journal of Education Research*.  
<https://doi.org/10.38140/ijer-2023.vol5.09>.
- Akhmetova, G. K., & Murzalinova, A. Zh. (2018). Stem-образование как направление обновления содержания образования в республике Казахстан [STEM education as a path to update the curriculum of education in the Republic of Kazakhstan]. *Methodist*, (4), 2-5. Retrieved from  
<https://www.elibrary.ru/item.asp?id=35330483>
- Almukhambetova, A. (2024). Exploring STEM teacher educators' gender awareness and understanding of gender-responsive pedagogies in Kazakhstan. In *The political economy of education in Central Asia: Evidence from the field* (pp. 97-115). Singapore: Springer Nature Singapore.
- Almukhambetova, A. (2025). Trends and challenges in STEM education in Kazakhstan. *Advances in Teaching and Teacher Education*, 137.
- Azhmukhambetov, A. (2020). Teachers' experiences of the updated pedagogy within the scope of the curriculum reform: A case study of two mainstream schools in Kazakhstan. *Nazarbayev University*.
- Babayeva, Z. (2023). DETERMINATION OF TEACHING STRATEGIES CONSIDERED NECESSARY IN TEACHING BIOLOGY. *International Journal of Educational Spectrum*. <https://doi.org/10.47806/ijesacademic.1273224>.

- Balta, N., Japashov, N., Karimova, A., Agaidarova, S., Abisheva, S., & Potvin, P. (2023, May). Middle and high school girls' attitude to science, technology, engineering, and mathematics career interest across grade levels and school types. In *Frontiers in Education* (Vol. 8, p. 1158041). Frontiers Media SA.
- Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review*, 84(2), 191.
- Beyer, C., Delgado, C., Davis, E., & Krajcik, J. (2009). Investigating Teacher Learning Supports in High School Biology Curricular Programs to Inform the Design of Educative Curriculum Materials. *Journal of Research in Science Teaching*, 46, 977-998. <https://doi.org/10.1002/TEA.20293>.
- Birzina, R., Pigozne, T., & Lapina, S. (2021). Trends in STEM Teaching and Learning within the Context of National Education Reform. . <https://doi.org/10.22616/REEP.2021.14.004>.
- Boakye, C., & Ampiah, J. (2017). Challenges and Solutions: The Experiences of Newly Qualified Science Teachers. *SAGE Open*, 7. <https://doi.org/10.1177/2158244017706710>.
- Borgerding, L. A. (2017). High school biology evolution learning experiences in a rural context: a case of and for cultural border crossing. *Cultural Studies of Science Education*, 12, 53-79.
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101.
- Carvalho, Í., El-Hani, C., & Nunes-Neto, N. (2020). How Should We Select Conceptual Content for Biology High School Curricula?. *Science & Education*, 29, 513-547. <https://doi.org/10.1007/s11191-020-00115-9>.

- Cimer, A. (2012). What makes biology learning difficult and effective: Students' views. *Educational research and reviews*, 7(3), 61.
- Cimer, A. (2012). What makes biology learning difficult and effective: Students' views. *Educational Research and Reviews*, 7(3), 61-71.
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education (8th ed.)*. Routledge.
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education (8th ed.)*. Routledge. <https://doi.org/10.4324/9781315456539>
- Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education (8th ed.)*. Routledge. <https://doi.org/10.4324/9781315456539>
- Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches (5th ed.)*. Sage Publications.
- Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research (3rd ed.)*. Sage Publications.
- Daganasol, R., Macasadog, D., Pilande, C., & Tan, M. (2020). A Matrix of Strategies in Teaching Biology: An Input to Pre-Service Teachers. *International Journal of Innovative Research and Development*. <https://doi.org/10.24940/ijird/2020/v9/i1/jan20062>.
- Dah, E. M. (2020). *Assessing senior high school biology students' science process skills* (Doctoral dissertation, University of Cape Coast).
- Diki, D. (2013). Creativity for Learning Biology in Higher Education. , 3, 3. <https://doi.org/10.5642/LUX.201303.03>.
- Elkhidir, N. (2020). Effective Teaching strategies in biological education: present and future prospects. *Open Science Journal*. <https://doi.org/10.23954/osj.v5i4.2550>.

- Elster, D. (2009). Biology in context: Teachers' professional development in learning communities. *Journal of Biological Education*, 43(2), 53–61.  
<https://doi.org/10.1080/00219266.2009.9656162>
- Etobro, A., & Fabinu, O. (2017). STUDENTS' PERCEPTIONS OF DIFFICULT CONCEPTS IN BIOLOGY IN SENIOR SECONDARY SCHOOLS IN LAGOS STATE. *Global Journal of Educational Research*, 16, 139-147.  
<https://doi.org/10.4314/gjedr.v16i2.8>.
- Fauzi, A., & Mitalistiani, M. (2018). High school biology topics that perceived difficult by undergraduate students. *Didaktika Biologi: Jurnal Penelitian Pendidikan Biologi*, 2(2), 73-84.
- Fauzi, A., & Mitalistiani, M. (2018). HIGH SCHOOL BIOLOGY TOPICS THAT PERCEIVED DIFFICULT BY UNDERGRADUATE STUDENTS. *DIDAKTIKA BIOLOGI: Jurnal Penelitian Pendidikan Biologi*.  
<https://doi.org/10.32502/DIKBIO.V2I2.1242>.
- Fauzi, A., Rosyida, A., Rohma, M., & Khoiroh, D. (2021). The difficulty index of biology topics in Indonesian Senior High School: Biology undergraduate students' perspectives. *JPBI (Jurnal Pendidikan Biologi Indonesia)*.  
<https://doi.org/10.22219/JPBI.V7I2.16538>.
- Fetters, M. D., Curry, L. A., & Creswell, J. W. (2013). Achieving integration in mixed methods designs—principles and practices. *Health Services Research*, 48(6pt2), 2134-2156.
- Field, A. (2017). *Discovering statistics using IBM SPSS statistics (5th ed.)*. Sage.
- Field, A. (2017). *Discovering statistics using IBM SPSS statistics (5th ed.)*. Sage Publications.

- Glasser, V., Bitencourt, C., Oliveira, L., Pierre, P., & Fioreze, A. (2018). Perception of Students from a High School of Curitiba-SC about "Cell Biology". , *16*, 9. <https://doi.org/10.16923/REB.V16I0.830>.
- Hiltunen, M., Kärkkäinen, S., & Keinonen, T. (2020). Biology student teachers' dialogic talk in inquiry-based instruction. *Journal of Biological Education*, *54*, 300 - 314. <https://doi.org/10.1080/00219266.2019.1575264>.
- Ilma, S., Al-Muhdhar, M. H. I., Rohman, F., & Saptasari, M. (2020). The correlation between science process skills and biology cognitive learning outcome of senior high school students. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *6*(1), 55–64.
- John Rae N. Sadera , Rianna Yvette S. Torres , Danilo V. Rogayan. Jr. (2020). Challenges Encountered by Junior High School Students in Learning Science: Basis for Action Plan. *Universal Journal of Educational Research*, *8*(12A), 7405 - 7414. DOI: 10.13189/ujer.2020.082524.
- Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research*, *1*(2), 112-133.
- Kennedy, M. (2016). How Does Professional Development Improve Teaching?. *Review of Educational Research*, *86*, 945 - 980. <https://doi.org/10.3102/0034654315626800>.
- Koba, S., & Tweed, A. (2009). *Hard-to-teach biology concepts: A framework to deepen student understanding*. NSTA Press.
- Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement*, *30*(3), 607-610.
- Labak, I., & Blažetić, S. (2023). A successful learning environment for biology teachers in higher education: Needs assessment. *Journal of Education and e-Learning Research*. <https://doi.org/10.20448/jeelr.v10i3.4919>.

- Labov, J., Reid, A., & Yamamoto, K. (2010). Integrated Biology and Undergraduate Science Education: A New Biology Education for the Twenty-First Century?. *CBE Life Sciences Education*, 9, 10 - 16. <https://doi.org/10.1187/cbe.09-12-0092>.
- Lay, C. D., Allman, B., Cutri, R. M., & Kimmons, R. (2020). Examining a decade of research in online teacher professional development. *Frontiers in Education*, 5, 573129. <https://doi.org/10.3389/feduc.2020.573129>
- Loehr, J., Almarode, J., Tai, R., & Sadler, P. (2012). High school and college biology: a multi-level model of the effects of high school courses on introductory course performance. *Journal of Biological Education*, 46, 165 - 172. <https://doi.org/10.1080/00219266.2011.617767>.
- McLaughlin, C., Winter, L., & Yakavets, N. (Eds.). (2023). *Mapping Educational Change in Kazakhstan*. Cambridge University Press.
- McLure, F. I., Tang, K. S., & Williams, P. J. (2022). What do integrated STEM projects look like in middle school and high school classrooms? A systematic literature review of empirical studies of iSTEM projects. *International Journal of STEM Education*, 9(1), 73.
- Mehisto, P., Winter, L., Kambatyrova, A., & Kurakbayev, K. (2022). CLIL as a conduit for a trilingual Kazakhstan. *The Language Learning Journal*, 51, 691 - 705. <https://doi.org/10.1080/09571736.2022.2056627>.
- Mehmood, N., Anwer, M., & Tatlah, A. (2019). Effect of Combined Teaching Strategies on Higher Order Thinking Skills (HOTS) of Biology Students. *Global Regional Review*. [https://doi.org/10.31703/GRR.2019\(IV-I\).33](https://doi.org/10.31703/GRR.2019(IV-I).33).
- Ministry of Enlightenment (2022). Об утверждении государственной программы обновленного содержания образования в Казахстане (Order No. 467). Retrieved from <https://adilet.zan.kz>

- Ministry of Enlightenment (2022). Об утверждении типовых учебных программ по общеобразовательным предметам и курсам по выбору уровней начального, основного среднего и общего среднего образования (Order No. 399). Retrieved from <https://adilet.zan.kz>
- Nagle, B. (2013). Preparing high school students for the interdisciplinary nature of modern biology. *CBE—Life Sciences Education*, 12(2), 144-147.
- NVivo. (2021). *NVivo - Qualitative Data Analysis Software*. QSR International. <https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home>
- Owens, M., Trujillo, G., Seidel, S., Harrison, C., Farrar, K., Benton, H., Blair, J., Boyer, K., Breckler, J., Burrus, L., Byrd, D., Caporale, N., Carpenter, E., Chan, Y., Chen, J., Chen, L., Chen, L., Chu, D., Cochlan, W., Crook, R., Crow, K., Torre, J., Denetclaw, W., Dowdy, L., Franklin, D., Fuse, M., Goldman, M., Govindan, B., Green, M., Harris, H., He, Z., Ingalls, S., Ingmire, P., Johnson, A., Knight, J., LeBuhn, G., Light, T., Low, C., Lund, L., Márquez-Magaña, L., Miller-Sims, V., Moffatt, C., Murdock, H., Nusse, G., Parker, V., Pasion, S., Patterson, R., Pennings, P., Ramirez, J., Ramirez, R., Riggs, B., Rohlf, R., Romeo, J., Rothman, B., Roy, S., Russo-Tait, T., Sehgal, R., Simonin, K., Spicer, G., Stillman, J., Sweig, A., Tempe, L., Vredenburg, V., Weinstein, S., Zink, A., Kelley, L., Domingo, C., & Tanner, K. (2018). Collectively Improving Our Teaching: Attempting Biology Department-wide Professional Development in Scientific Teaching. *CBE Life Sciences Education*, 17. <https://doi.org/10.1187/cbe.17-06-0106>.
- Patton, M. Q. (2015). *Qualitative research & evaluation methods (4th ed.)*. Sage Publications.

- Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education, 95*, 309-327.  
<https://doi.org/10.1016/j.compedu.2016.02.002>
- Priestley, M., Biesta, G. J., Philippou, S., & Robinson, S. (2015). The teacher and the curriculum: Exploring teacher agency. *The SAGE handbook of curriculum, pedagogy and assessment*, 187-201.
- Qualtrics. (2021). Qualtrics XM // *The Leading Experience Management Software*.  
<https://www.qualtrics.com>
- Rozenszajn, R., & Yarden, A. (2014). Expansion of biology teachers' pedagogical content knowledge (PCK) during a long-term professional development program. *Research in Science Education, 44*(2), 189–213. <https://doi.org/10.1007/s11165-013-9378-6>
- Shan, L. (2020). Research on the Path of Reform and Innovation of Biology Teaching Mode in Middle School. . <https://doi.org/10.23977/ICSSEM2020.038>.
- Stohlmann, M., Moore, T., & Roehrig, G. (2012). Considerations for Teaching Integrated STEM Education. *Journal of Pre-College Engineering Education Research, 2*, 28-34. <https://doi.org/10.5703/1288284314653>.
- Suleimenova, E., Kozhamkulova, G., Urazaeva, K., (2018). School textbooks with updated content in Kazakhstan in the aspect of education reform. *Journal of Siberian Federal University, 11*, 987-1001. <https://doi.org/10.17516/1997-1370-0288>.
- Syed Abdul Manan, Symbat Mukhamediyeva, Sabina Kairatova, Mir Afzal Tajik & Anas Hajar (2024) *Policy from below: STEM teachers' response to EMI policy and policy-making in the mainstream schools in Kazakhstan, Current Issues in Language Planning, 25*:1, 89-109, DOI: 10.1080/14664208.2023.2243170
- Tabachnick, B. G., & Fidell, L. S. (2019). *Using multivariate statistics (7th ed.)*. Pearson.

- Tajik, M.A., Shamatov, D., & Phillipova, L. (2022). Stakeholders' perceptions of the quality of education in rural schools in Kazakhstan. *Improving Schools*, 25(2), 187-204.
- Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Sage Publications.
- Tekkaya, C., Özkan, Ö., & Sungur, S. (2001). Biology concepts perceived as difficult by turkish high school students. *Hacettepe Universitesi Egitim Fakultesi Dergisi-hacettepe University Journal of Education*, 21.
- Tripto, J., Assaraf, O.B.Z. & Amit, M. Recurring patterns in the development of high school biology students' system thinking over time. *Instr Sci* 46, 639–680 (2018).  
<https://doi.org/10.1007/s11251-018-9447-3>
- Williams, A., & O'Dowd, D. (2020). Seven practical strategies to add active learning to a science lecture. *Neuroscience Letters*, 743.  
<https://doi.org/10.1016/j.neulet.2020.135317>.
- Wilson, E., Turner, F., Sharimova, A., & Brownhill, S. (2013). Reform at scale: Teacher development in Kazakhstan. *European Educational Research Association*, 1-18.
- World Medical Association. (2013). World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA*, 310(20), 2191-2194.
- Yakavets, N., Winter, L., Malone, K., Zhontayeva, Z., & Khamidulina, Z. (2023). Educational reform and teachers' agency in reconstructing pedagogical practices in Kazakhstan. *Journal of Educational Change*, 24(4), 727-757.
- Yu, J., Li, C., & Li, G. (2022). Alignment between biology curriculum standards and five textbook editions: a content analysis. *International Journal of Science Education*, 44(14), 1–20. <https://doi.org/10.1080/09500693.2022.2119621>

Zharylkassyn, M. B. (2023). Integrating continuing professional development with education system reform in Kazakhstan. *Challenges of Science, VI*, 22–28.

Zhumabay, N., Varis, S., Abylkassymova, A., Balta, N., Bakytказы, T., & Bowen, G. M. (2024). Mapping the Kazakhstani STEM Education Landscape : A Review of National Research. *European Journal of STEM Education, 9*(1), 16.

<https://doi.org/10.20897/ejsteme/15576>

Zulyusri, Z., Elfira, I., Lufri, L., & Santosa, T. A. (2023). Literature study: Utilization of the PjBL model in science education to improve creativity and critical thinking skills. *Jurnal Penelitian Pendidikan IPA, 9*(1), 133–143.

<https://doi.org/10.29303/jppipa.v9i1.2555>

## Appendices

### Appendix A: Declaration of the Use of Generative AI



I hereby declare that I have read and understood NUGSE's policy concerning appropriate use of AI and composed this work independently (please check one):

- with the use of artificial intelligence tools, or
- without the use of artificial intelligence tools.

(If you have used AI tools as defined in the GSE policy document, please complete the rest of this form.)

During the preparation of this thesis/examination, I used Claude.ai, X Grok, OpenAI ChatGPT and Google Gemini to brainstorm, create ideas and for literature search.

I also declare that I,

- am aware of the capabilities and limitations of AI tool(s),
- have verified that the content generated by AI systems and adopted by me is factually correct,
- am aware that as the author of this thesis I bear full responsibility for the statements and assertions made in it,
- have submitted complete and accurate information about my use of AI tools in this work, and

- acknowledge that there may be disciplinary consequences if I have not followed NUGSE's guidelines regarding AI appropriate use.

Name: Sagyndyk Sagadinov

Signature:

Date: 27.04.2025

*Saga*

## **Appendix B: Survey Instrument**

### **Research Information and Ethics Statement**

Dear Participant,

My name is Sagyndyk Sagadinov, I am a 2nd year master's student at the Graduates School of Education at Nazarbayev University. Thank you for considering participation in this survey. This survey is part of my study titled "Examining Teachers' Perceptions about Teaching Difficult Concepts in Biology in Upper Secondary School Curriculum in Kazakhstan". By understanding your experiences, we hope to gain insights that could support improved teaching strategies and resources for biology educators.

Ethics and Confidentiality:

- **Voluntary Participation:** Your participation in this study is entirely voluntary. You may choose to skip any question or stop participating at any time without any consequence.
- **Confidentiality:** All information you provide will be kept confidential. Your responses will be anonymized, and no identifying information will be shared in any reports or publications resulting from this study. The data will be reported in aggregate form, ensuring that individual participants cannot be identified.
- **Data Protection:** All data collected will be securely stored and accessible only to the research team at Nazarbayev University. It will be used solely for academic purposes and will be deleted after the research is completed.
- **Independent Contact:** If you are not satisfied with how this study is being conducted, or if you have any concerns, complaints, or general questions about the research or your rights as a participant, please contact the NUGSE Research Committee to speak to someone independent of the research team at +7 7172 709359. You can also write an email to the NUGSE Research Committee at [gse\\_researchcommittee@nu.edu.kz](mailto:gse_researchcommittee@nu.edu.kz)

Once you read the consent form, please indicate your willingness to take part in this survey by clicking on the appropriate box below:

I am willing to take part and for my responses to be used as data for the above research purposes.

I am not willing to take part and would like to exit this survey.

### **Survey Questions for Teachers' Perceptions on Teaching Difficult Concepts in Biology**

#### **Section 1: Demographics**

1. What is your gender?
  - a. Male
  - b. Female
  - c. Prefer not to say
  
2. How many years of experience do you have teaching biology?
  - a. 0-5 years
  - b. 6-10 years
  - c. 11-15 years
  - d. More than 15 years
  
3. What is your highest educational qualification?
  - a. Bachelor's Degree
  - b. Master's Degree or Specialist's degree
  - c. PhD or Doctorate
  
4. In what type of school do you teach?
  - a. Urban
  - b. Rural
  
5. What is the average class size of your biology classes?
  - a. Less than 20 students
  - b. 21-30 students
  - c. 31-40 students
  - d. More than 40 students
  
6. What grades do you teach? (Select all that apply)
  - a. 7th grade
  - b. 8th grade
  - c. 9th grade
  - d. 10th grade
  - e. 11th grade

## **Section 2: Teaching Experience with Difficult Biology Concepts**

1. Which of the following topics from the biology curriculum for grades 7–11 do you find most difficult to teach?

(Please rate the difficulty of each topic using the scale below):

1 = Very Easy to Teach

2 = Easy to Teach

3 = Moderately Difficult to Teach

4 = Difficult to Teach

5 = Very Difficult to Teach

### **Grade 7:**

- Ecosystems (e.g., food chains, ecological succession, anthropogenic factors)
- Classification of organisms (e.g., kingdoms, systematic groups, dichotomous keys)
- Cell biology (e.g., plant and animal cell structure, organelles visible under light microscopes)
- Water and organic compounds (e.g., properties of water, role of macro- and microelements)
- Transport in plants (e.g., structure of stems and roots, xylem and phloem functions)
- Photosynthesis (e.g., factors affecting photosynthesis, leaf structure)
- Respiration (e.g., aerobic and anaerobic respiration in plants and animals)
- Excretion (e.g., products of metabolism, plant and animal excretory systems)
- Movement (e.g., plant tropisms, adaptations for locomotion in animals)
- Coordination and regulation (e.g., nervous system types, reflex arcs, sleep cycles, stress management)

### **Grade 8:**

- Cell biology (e.g., prokaryotic vs. eukaryotic cells, diversity of plant and animal tissues)
- Molecular biology (e.g., carbohydrates, proteins, lipids, nucleic acids)
- Biodiversity (e.g., algae, mosses, ferns, fungi, chordates, arthropods)
- Nutrition (e.g., digestive system of humans and animals, vitamins, diseases)
- Transport in animals (e.g., blood components, immune responses, circulatory systems in different species)
- Respiration (e.g., gas exchange, respiratory mechanisms, lung capacity)
- Excretion (e.g., nephron function, urinary system, skin in thermoregulation)
- Biophysics (e.g., movement and skeletal adaptations in humans and animals)
- Coordination and regulation (e.g., sensory organs, endocrine system, hormonal regulation)

### **Grade 9:**

- Cell biology (e.g., cell organelles and their functions, cell membrane transport)
- Molecular biology and biochemistry (e.g., DNA structure and replication, protein synthesis)
- Genetics (e.g., Mendelian inheritance, mutations, chromosomal theory)
- Evolution and biodiversity (e.g., mechanisms of evolution, adaptive traits)
- Ecology (e.g., population dynamics, biogeochemical cycles, human impact on ecosystems)

- Biotechnology (e.g., bacterial applications, antibiotics, viral structure, and replication)
- Reproduction (e.g., mitosis and meiosis, gametogenesis in plants and animals)

**Grade 10-11:**

- Molecular biology and biochemistry (e.g., metabolism, ATP synthesis, Krebs cycle)
- Genetics and heredity (e.g., dihybrid crosses, genetic code, polygenic traits)
- Evolution (e.g., speciation, evidence of evolution, phylogenetic trees)
- Ecology (e.g., conservation, climate change modeling, energy flow in ecosystems)
- Reproduction and development (e.g., embryogenesis, hormonal control in humans and plants)
- Biotechnology and bioinformatics (e.g., PCR, GMOs, ethical issues, bioinformatics tools)
- Human anatomy and physiology (e.g., circulatory, respiratory, excretory systems)

2. This factor contributes to the difficulty of teaching biology topics. (Select all that apply)  
(To what extent do you agree or disagree with this following statement, 1 = I absolutely disagree, 5 = I absolutely agree)

- a. Complexity of the content
- b. Lack of student readiness
- c. Abstract nature of the concepts
- d. Insufficient teaching resources
- e. Lack of laboratory equipment
- f. Time constraints in the curriculum

3. I feel confident in my ability to explain complex biological concepts to my students.  
(To what extent do you agree or disagree with this following statement, 1 = I absolutely disagree, 5 = I absolutely agree)

4. I feel comfortable with the current biology curriculum I am expected to teach.  
(To what extent do you agree or disagree with this following statement, 1 = I absolutely disagree, 5 = I absolutely agree)

**Section 3: Use of Resources and Teaching Strategies**

1. Which of the following resources do you use to teach biology? (Select all that apply)

- a. Textbooks
- b. Digital simulations or virtual labs
- c. Laboratory experiments
- d. Online videos or tutorials

- e. Project-based learning
  - f. Real-world case studies
2. How often do you use digital tools (e.g., simulations, online platforms) to assist with teaching difficult biology topics?

- a. Never
- b. Rarely
- c. Sometimes
- d. Often
- e. Always

3. I feel that I have adequate access to the resources and equipment needed to effectively teach complex biology topics? (To what extent do you agree or disagree with this following statement, 1 = I absolutely disagree, 5 = I absolutely agree)

#### **Section 4: Professional Development and Support**

1. During the last 12 months, did you participate in any of the following professional development activities? (Select all that apply)

- a. Workshops or seminars focused on biology teaching.
- b. Peer collaboration or study groups with other biology teachers.
- c. Online courses or webinars about teaching methodologies.
- d. Observing other teachers' biology lessons (peer observation).
- e. Mentoring or coaching by more experienced teachers.
- f. Participation in a professional network or association (e.g., biology teachers' association).
- g. University or academic training programs related to biology.
- h. Self-guided learning (e.g., reading books, articles, or research papers about teaching biology).
- i. No, I did not participate in any professional development activities.

3. To what extent do you agree that professional development has been useful in improving your ability to teach difficult concepts in biology? (1 = Strongly Disagree, 5 = Strongly Agree)

4. What type of support would be most helpful for you in teaching difficult biology topics? (Select all that apply)

- a. More professional development opportunities
- b. Access to better teaching resources (e.g., updated textbooks, digital tools)
- c. Access to advanced laboratory equipment
- d. Collaboration with other biology teachers from other schools
- e. Online resources or tutorials for students
- f. Smaller class sizes

5. How would you rate your current level of comfort in explaining challenging biological concepts to your students?

1 = I would appreciate more support

2 = I sometimes struggle and could use additional resources

3 = I feel moderately comfortable but see room for improvement

4 = I feel comfortable in most cases

5 = I feel very comfortable and confident

### **Section 5: Optional Interview Participation**

1. Would you be interested in participating in a follow-up interview to provide more detailed information about your experiences and strategies in teaching difficult biology concepts?
  - a. Yes
  - b. No
  
2. If yes, please provide your contact information below (e.g., email or phone number):

## **Appendix C: Interview Instrument**

### **Qualitative Interview Questions: Teaching Difficult Concepts in Biology**

#### **Section 1: Background Information**

1. Can you briefly describe your teaching experience in biology?

- How long have you been teaching?
- What grades do you currently teach?

2. Can you tell me about the school environment you work in?

- Is it in an urban or rural setting?
- What resources are available to you?

#### **Section 2: Experiences with Teaching Difficult Biology Concepts**

1. What specific biology topics do you find most difficult to teach?

- Why do you think these topics are particularly challenging?

2. Can you describe your experience when teaching these challenging topics?

- What challenges do you encounter from students?
- How do students typically respond to these topics?

3. Do you think the complexity of certain biological concepts affects student engagement and understanding?

- How do students react when learning these topics?

#### **Section 3: Teaching Strategies and Resources**

1. What teaching strategies do you find most effective when tackling difficult biology concepts?

- Can you share a specific example of a strategy you've used successfully?

2. What resources (e.g., textbooks, lab equipment, digital tools) do you use when teaching difficult concepts?

- Are these resources helpful in making complex topics more understandable?
- Are there any resources you wish you had access to but don't?

3. How often do you use digital tools or simulations to teach difficult concepts?

- How do you think these tools impact student learning?

#### **Section 4: Professional Development and Support**

1. Can you describe any professional development programs or training you have attended that focused on teaching biology?

- Did these programs help you with teaching complex topics? If so, how?

2. Do you feel supported by your school and the educational system in teaching difficult biology concepts?

- What additional support or resources would be helpful for you?

3. Have you collaborated with other teachers or educational experts to find new ways to teach complex biology concepts?

- Can you share any insights from such collaborations?

#### **Section 5: Reflection and Suggestions**

1. In your opinion, what could be done to make the teaching of complex biology topics easier for teachers and students?

- Are there any changes in curriculum, resources, or teaching methods you would suggest?

2. If you could design a professional development program specifically focused on teaching difficult biology concepts, what would it include?

- What skills or resources would you want to focus on?

3. Do you have any final thoughts or suggestions on how biology education can be improved in Kazakhstan, especially in relation to complex concepts?

#### **Follow-Up Questions**

- Can you elaborate on that?
- Why do you think that strategy worked (or didn't work)?
- Can you give me an example?