УДК 21474;
ГРНТИ 14.85.01
https://doi.org/10.47526/2023-4/2524-0080.04

B. DAULESHIAR[1], M. ABDULBAKIOGLU[2], F. KASSIMOV[3]
[1]Master's Student of SDU University, (Kazakhstan, Almaty), e-mail: bakytali@inbox.ru
[2]PhD, professor of SDU University (Kazakhstan, Almaty), e-mail: m.abdulbakiogly@sdu.edu.kz
[3]SDU University, (Kazakhstan, Almaty), e-mail: farid.vafazov459@gmail.com

INCREASING STUDENTS ' INTEREST IN THE SUBJECT OF PHYSICS BY INTEGRATING THE SCIENCE OF ROBOTICS

Abstract. The rapid advancement of technology has significantly influenced the field of scientific research and innovation. This includes various areas such as robotics, physics, integration, and the application of knowledge. Designing experiments to test and analyze the impact of these advancements requires careful consideration. This study was conducted in the Almaty region of Kazakhstan, specifically in the 8th grade at Aset Beyseuov schools, to assess the learning outcomes of students in robotics in the 2022-2023 academic year. The participants were selected based on the school's curriculum and were part of a specialized cluster for robotics education. Following the eighth session, a questionnaire based on Torranstyn's study (1979) was administered to gather data on variables such as intrinsic motivation, student engagement, innovations, and career aspirations. As a result, 10 different tests and physics-related robotic construction activities were conducted. Covariance analysis was utilized to analyze the data. The findings of the study revealed a positive correlation between robotics education and students' academic progress in physics.
Keywords: robotics training, creativity, education, students, physics.

Б. Дәулешиар[1], М. Абдулбакиоглы[2], Ф. Қасымов[3]
[1]Сулейман Демирел университетінің магистранты (Қазақстан, Алматы қ.), e-mail: bakytali@inbox.ru
[2] PhD, профессор Сулейман Демирел университеті (Қазақстан, Алматы қ.), e-mail: m.abdulbakiogly@sdu.edu.kz
[3]Сулейман Демирел университеті (Қазақстан, Алматы қ.), e-mail: farid.vafazov459@gmail.com

Робототехника ғылымын кіріктіру арқылы оқушылардың физика пәніне деген қызығушылығын арттыру

Аңдатпа. Технологияның қарқынды дамуы ғылыми зерттеулер мен инновациялар саласына айтарлықтай әсер етті. Бұған робототехника, физика, интеграция және білімді қолдану сияқты әртүрлі салалар кіреді. Осы жетістіктердің әсерін сынау және талдау үшін эксперименттерді жобалау мұқият қарауды талап етеді. Бұл зерттеу Қазақстанның Алматы облысында, атап айтқанда Әсет Бейсеуов атындағы мектептердің 8-сыныбында 2022-2023 оқу жылында робототехника пәнінен оқушылардың оқу нәтижелерін бағалау мақсатында жүргізілді. Қатысушылар мектептің оқу бағдарламасы негізінде таңдалды және робототехника бойынша білім беру бойынша мамандандырылған кластердің бір бөлігі болды. Сегізінші сессиядан кейін ішкі мотивация, студенттердің белсенділігі, инновациялар және мансаптық талпыныстар сияқты айнымалылар бойынша деректерді жинау үшін Торранстиннің зерттеуіне негізделген сауалнама (1979) жүргізілді. Нәтижесінде 10 түрлі сынақтар мен физикаға байланысты роботтандырылған құрылыс жұмыстары жүргізілді. Деректерді талдау үшін коварианттық талдау қолданылды. Зерттеу нәтижелері робототехника бойынша білім мен студенттердің физикадағы оқу үлгерімі арасындағы оң

корреляцияны анықтады.

Түйін сөздер: робототехниканы оқыту, шығармашылық, білім беру, студенттер, физика.

Б. Даулешяр[1], М. Абдулбакиоглы[2], Ф. Касимов[3]

[1]*Магистрант Университет им. Сулеймана Демиреля, (Казахстан, г. Алматы), e-mail: bakytali@inbox.ru*

[2]*PhD, профессор Университет им. Сулеймана Демиреля, (Казахстан, г. Алматы), e-mail: m.abdulbakiogly@sdu.edu.kz*

[3]*Университет им. Сулеймана Демиреля, (Казахстан, г. Алматы), e-mail: farid.vafazov459@gmail.com*

Повышение интереса учащихся к предмету физика за счет интеграции науки робототехники

Аннотация. Быстрое развитие технологий существенно повлияло на область научных исследований и инноваций. Сюда входят различные области, такие как робототехника, физика, интеграция и применение знаний. Разработка экспериментов для проверки и анализа влияния этих достижений требует тщательного рассмотрения. Данное исследование проводилось в Алматинской области Казахстана, а именно в 8 классе школы имени Асета Бейсеуова, с целью оценки результатов обучения учащихся по робототехнике в 2022-2023 учебном году. Участники были отобраны на основе школьной программы и входили в специализированный кластер по обучению робототехнике. После восьмой сессии была использована анкета, основанная на исследовании Торранстина (1979), для сбора данных о таких переменных, как внутренняя мотивация, вовлеченность студентов, инновации и карьерные устремления. В результате было проведено 10 различных испытаний и роботостроительных работ, связанных с физикой. Для анализа данных использовался ковариационный анализ. Результаты исследования выявили положительную корреляцию между обучением робототехнике и успеваемостью студентов по физике.

Ключевые слова: обучение робототехнике, творчество, образование, студенты, физика.

Introduction

The subject of physics has often been perceived as challenging and uninteresting by students, particularly girls. However, recent research suggests that integrating the science of robotics into physics education can be an effective strategy for increasing students' interest in the subject. This study aims to synthesize the findings from various studies to explore the impact of integrating robotics on students' interest in physics. Today, the science of robotics is a promising area that is leading to human life. Students are growing up in a completely different world from the world of their parents and grandparents. To succeed in today's "creative society," students must learn to think creatively, plan systematically, analyze critically, and continue learning [1].

Robotics science is closely related to such school subjects as computer science, physics, and mathematics. Among these disciplines, the programming of robot-equipped devices (Motors and sensors) belongs to the field of physics. When creating programs, it is necessary to understand the essence of the sensor operation (the physical laws on which its operation is based), consider the measurement inaccuracies of the sensor, etc. Physics as the scientific basis of technology is constantly in the lead, because the most important areas of technical progress are based on it. The most important sections of Physical Science for robotics are mechanics and electronics. Mathematics as a means of scientific knowledge contributes to solving problems related to angles, degrees, coefficients and proportions in robotics in education. Together, physical and mathematical knowledge allows you to calculate the trajectory of the robot's movement and find the values of physical quantities [2].

To increase the student's interest by integrating physics with robotics, you must first learn what integration is. Generally speaking, the integration it has to do with the creation of a larger unit from smaller units, just as it happens with the inverse calculation of a mathematical derivative or with new concepts that introduce them into already established knowledge. Integration in education (usually associated with the beginning of schooling) is a series of procedures and rules that aim to adapt the child to the community and learning process. It considers their family, social and economic conditions, through case studies, monitoring of progress, and various types of learning incentives. This is a complex dynamic, especially in special educational situations for various reasons. The integration of education is to discover the basic or majority model of formal education considering the individual needs of each child, thus capturing and recovering those who are more likely to drop out of school.

The integration of educational technologies into teaching and learning processes has become a significant focus in the field of education worldwide. E-learning, as the most widely used form of information and communication technologies (ICT), has introduced a new dimension to educational practices at both basic and advanced levels [3; 4; 5]. Modern technologies play a crucial role in enhancing students' skills, knowledge, and motivation to learn [6]. In our current education system, there is a growing emphasis on utilizing technology to improve the quality of education and cultivate individuals with creative thinking, problem-solving abilities, and the capacity to overcome challenges through innovative ideas [7].

One technology that has revolutionized the world is robotics, which can serve as an engaging platform for learning various subjects, including computers, electronics, mechanical engineering, and languages [8]. Studies have shown that young children perform better on exams and display increased interest when language learning involves interaction with a robot compared to traditional methods such as audiotapes and books [9]. The positive effect is often attributed to the "embodiment" and physical presence of robots, which make programming outcomes visible and provide continuous formative assessment of learning progress, thereby encouraging students' engagement. In light of these findings, educational institutions in developing countries have recently made efforts to introduce theoretical approaches, presentation-based lectures, and robotic activities to enhance the quality of teaching and learning [10].

Robotics, encompassing the design, construction, launch, and operation of robots, offers a diverse and widespread field that caters to the curiosity and diverse-seeking tendencies of adolescent students [11]. There are numerous recommendations for integrating robotic systems into school education, as learning through robotics creates an active and interactive learning environment that emphasizes student participation. Thus, the use of robotic training technology in the school curriculum can enrich the achievement of educational goals through innovative and modernized teaching methods [12]. Due to its interdisciplinary nature, robotics presents an attractive approach to education, requiring expertise in mathematics and aesthetics. Mathematics strengthens students' problem-solving and creative thinking skills, making robotics an effective tool for developing these cognitive abilities [13]. However, the adoption of technological advancements in education, especially robotics-mediated education, remains limited. This is primarily due to factors such as a lack of technology-based educational thinking, inadequate infrastructure in schools to support robotics training workshops, the inability to design and produce robotic components within the country, and the high costs associated with implementing such an educational approach in schools.

Creativity, defined as the generation of new ideas and innovative products, is considered a fundamental cognitive characteristic of humanity. It involves problem-solving, idea generation, conceptualization, artistic expression, theorizing, and the production of unique creations [14]. Creativity is a developmental process characterized by innovation, adaptability, and self-realization, enabling individuals to find solutions to problems. While intelligence is associated with creativity, surveys have shown that a certain level of intelligence alone is insufficient. Individuals with average intelligence can exhibit pronounced creativity, as creativity is nurtured through effective training and learning experiences [15].

Research methods

The advancement of technology has significantly contributed to the expansion of knowledge in various fields, including robotics, physics, integration, and their practical applications. In this context, the design of experiments plays a crucial role in assessing and understanding the impact of these advancements. During the academic year 2022-23, a study was conducted in the Almaty region of Kazakhstan, specifically in a village called Kyzynagash, involving 112 male and female students from 8th grade at Ata and Ayel schools. These schools were selected based on their inclusion of robotics education in their curriculum. The participants were chosen through a cluster sampling technique to ensure representative samples from different geographical zones within the study area, including North, South, Central, East, and West.

The study employed a quasi-experimental design with pre-test measurements and utilized keywords derived from previous research, such as Torranstyn's study (1979). The questionnaire used in the study covered topics related to intrinsic motivation, self-efficacy, innovations, and interests, encompassing approximately 60 survey items. Additionally, ten tests and activities related to robotics and physics, such as constructing robotic devices, were conducted. To analyze the collected data, covariance analysis was applied. The results of the study revealed the positive influence of robotics education on students' motivation and their subsequent performance in physics. To evaluate students' creative abilities, the Torrance Creative Survey (1979) was employed. It encompassed four dimensions: turnover, adaptability, innovation, and detailed explanations. The survey consisted of 60 items presented on a Likert scale with 3 response options. Torrance (1979) developed and validated the survey, demonstrating robust psychometric properties. Abedy (1993) reported a total validity of 27% for the test, with liquidity validity at 9%, adaptability at 13%, innovation at 15%, and interpretation measurement at 24% [16]. These coefficients were statistically significant at a 5% level. The survey exhibited high reliability, with a Cronbach's alpha coefficient of .96, indicating its strong consistency. Scores on the questionnaire ranged from 60 to 180, with higher scores indicating greater creativity.

Moreover, a 10-item test was utilized to assess students' progress. The test's validity was confirmed by two examiners experienced in teaching physics and a dedicated teacher. The questions displayed an average complexity index of 92.69 and a severity index of 91.73, indicating appropriate levels of difficulty and discrimination. As part of the research tools, a comprehensive package of robotic design trainings was provided. This package included a full set of tools for creating a rescue robot and consisted of 8 lessons during which students were instructed in the utilization of these tools to construct a rescue robot. The accuracy of this training package was verified by technical experts from the Department of Education, and its reliability was assessed under the supervision of experts from the Ministry of Education.

Implementation approach, Education and Information Technologies

To carry out the test and balance the control and experimental groups, we divided the two groups of male and female students of 60 people equallyvaccording to their marks at the school, they were divided into two groups of 28 students vassessment cards. One group was defined as a control group and the other as a control group experimental. Thus, two control groups (n = 28 for each) and two experimental groups were formed groups (for each n = 28). In addition, the physics teacher it was one person. Robotics specialists with a bachelor's degree in electronics from Almaty university, whose specialty is devoted to the development of robotics, the development of robots, the creation of Applied tools and programming. These specialists can study the development of programs for ARM and AVR architectures, in some cases using robotic systems, electronic systems, and microcontrollers.

Table 1. Eighth sessions

Activity	Training subject	Media and training tools	Training method	Training by the use of robot in the physics class
First session	Condenser- condenser capacity	simple electrical circuit	the law of connecting conductors to each other	Practical activities such as creating and programming led circuits to understand how electrical and electronics are used in robotics
Second session	Electrical breakdown- condenser energy	Condenser-connection cablemultimeter	Closing the circuit and calculation of the condenser capacity by multimeter	General acquaintance with rescuer robotremembering the learned subjects – introduction to physical components of rescuer
Third session	Electrical circuit – the law of ohm	Cable – battery – resistance – ammeter - voltammeter	Closing resistance and measuring resistance of the object	Building sensors of rescuer robot
Fourth session	Resistance dependence of temperature and the relationship of opposites with each other	Conductor-battery-resistance – ammeter-voltammeter -	we carry out experimental work on the scheme	Rescue robot test
Fifth session	Magnetic-magnetic field lines of force	Magnet – paper – magnet filing	By doing the test, we observe the magnetic field through the test	Finalization of building the rescuer robot
Sixth session	Magnetic field in conductor, electromagnet and coils	Using animations on the website	With the use of animation on the website comment while reading	improve the performance of rescue robot
Seventh session	Magnetic properties of paramagnetic objects, paramagnetic substances-paramagnetic objects	Slides and video the level of molecules and atoms	Will give comments on pictures	Ways to increase the productivity of the robot
Eighth session	The phenomenon of electromagnetic induction and the law of lens	Electromagnet-Magnetism Galvanometer element	We study the law of the lens and electromagnetic induction making laboratory tools	Controlling and final testing of the rescuer robot
After the last session posttest	posttest	Researcher-made test	Conducting the test	

The materials were taught by a physics teacher (common to all four groups). Each lesson lasted 50 minutes. In each lesson, after the theoretical presentation of the materials, discussions were held with practical examples and the robotics teacher with the participation of a physics teacher taught students to create robots according to the content of the textbook. The students also created robots in collaboration with and using one another knowledge gained in physics lessons during eight lessons. The order of the Sessions was as follows (Table 1).

After the end of the eighth sessions, when the training on the creation of robots is completed, students were given a Torrance creative questionnaire to measure their creativity and the level of training. They filled out the questionnaire items in 80 minutes. In addition, the control a group that studied physics in eight lessons using traditional lessons teaching methods, Torrance completed the creative scale and learning level test 80 minutes at the end of the eighth session.

Table 2. Descriptive statistics for the research variables before and after robotics training

Groups Variables	Means after instruction		Means before instruction	
	Mean	SD	Mean	SD
Creativity	46.1	30.	5	.32
	11.1	29.0	20.3	84.1
Learning	14.15	72.1	51.19	75.2
	60.14	91.2	49.16	37.1

From the selected study sample, 56 (50%) of the participants were placed in the control group, while 56 (50%) of the participants were placed in the experimental group. In terms of age distribution, 27% of the participants were 11 years old, 41% were 12 years old, and 32% were 13 years old (Table 2). Descriptive statistics for the research variables were classified according to the research groups.

The average and standard deviation of training indicators (according to Table 1) showed that the creativity of students in a robotics-based classroom was higher compared to the Mean and standard deviation of creativity performance in their non-robotics-based classroom. Evaluation of the standard deviation before guidance was conducted to address the research hypothesis. The ANOVA method was employed to answer the research hypothesis in the study. The ANOVA results are presented in the following sections.

Examining ANOVA assumptions to implement ANOVA

Normality of the data:

Based on the analysis presented in Table 3, all *p*-values for the research variables were found to be greater than 0.05. These results indicate that the data distribution was deemed to be normal, as the null hypothesis could not be rejected. Therefore, parametric tests were employed for hypothesis testing in the research.

Table 3. Results of Normality of the Research Variables

One-Sample Kolmogorov-Smirnov Test				
	Creativity (pre-test)	Creativity (post-test)	Learning (pre-test)	Learning (post-test)
Kolmogorov-Smirnov Z	.832	1.034	.801	.752

Asymp. Sig. (2-tailed)	.481	.231	.456	.512

a. Test distribution is Normal

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1. Equivalence of ANOVA assumptions

Statistical index	F	df1	df2	Sig.
Learning	002/0	1	118	96/0
Creativity	13/0	1	118	71/0

Based on Table 3, the obtained F value did not reach statistical significance. Consequently, we can assume that the variances are equal, and therefore, the use of covariance is appropriate. The existence of the homogeneity hypothesis (regression) is shown in the Table 4.

Table 4. Results of regression analysis for homogeneity hypothesis, regression slopes of learning and creativity variables in the experimental groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Group learning effect	34/38	1	34/38	18/1	28/0
Group creativity effect	24/831	26	97/31	45/2	12/0

Based on the data provided in the preceding table, the bidirectional effect between the pre-test and the group was found to be statistically non-significant.

1. Hypothesis 1: Robotic training has no effects on the creativity of the 11th grade students in physics (Table 5).

Table 5. Summary of ANCOVA results for creativity in control and experimental groups while excluding the bidirectional effect

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Pre-test	18.680	1	18.680	66.884	.000	.364
group	1.835	1	1.832	6.564	.012	.553
Error	32.684	117	.279			
Total	1624.144	120				
Corrected Total	70.872	119				

Table 6. Pairwise Comparisons

(I) Group	(J) Group	Mean Difference	Std.	95%	Interval for

		(I-J)	Error	Confidence	Differencea
experimental	control	.295*	.115	Lower Bound	Upper Bound
				.012	.067
Control	experimental	−.295*	.115	.012	−.522

The mean difference is at the .05 level (Table 6). According to the information provided in the preceding table, (F (1, 120) = 6.56, p = 0.012, Eta = 0.55), a significant difference was observed between the experimental and control groups in terms of creativity posttests. This indicates that there is a noteworthy disparity in the creativity levels of the two groups after the intervention. The effect size, Eta, is calculated to be 0.55, suggesting that approximately 55% of the improvement in creativity within the experimental group can be attributed to the impact of robotics-based instruction. Based on these findings, it can be inferred that robotic-based instruction has the potential to influence the creativity level of 8th-grade students.

Adjustment for multiple comparisons: Bonferroni

The results of the Bonferroni analysis revealed a statistically significant diference in the creativity levels of the students between the control and experimental groups following the implementation of robotic-based instruction ($p < 0.05$).

2. Hypothesis 2: Robotic training does not affect the learning of the 8th grade students in physics (Table 7).

Table 7. Robotic training

Source	Type III Sum of Squares	df	Mean Square	F	Sig	Partial Eta Squared
Pre-test	173.612	1	173.612	105.625	.000	.473
Group	133.895	1	133.895	81.462	.000	.411
Error	192.306	117	1.644			
Total	39561.000	120				
Corrected Total	644.992	119				

a. R Squared = 702 (Adjusted R Squared = 697)

Table 8. Balanced means for the research groups and standard error and lower and upper bounds

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.a	95% Confidence Interval for Differencea	
experimental	control	2.232*	.247	.000	Lower Bound	Upper Bound
					1.742	2.721
Control	experimental	2.232*	.247	.000	−2.721	−1.742

The mean difference is significant at the .05 level (Table 8). According to the data presented in the table above (F (1, 120) = 81.46, p = 0/000, Eta = 0.41), a reliable difference was observed between the experimental and control groups. This indicates a significant discrepancy between the two groups in terms of the measurable variable. The magnitude of the effect, Eta, is estimated to be 0.41, which is about 41% of the improvements observed in the experimental group. Indicates that it can be attributed to the robot-based learning report. Thus, based on these results, we can conclude that robot-based learning affects the results of 8th grade students ' training in physics.

Results and discussion

Based on the findings of the research, it is evident that the incorporation of robotics training positively impacts students' creativity and their learning outcomes, particularly in the field of physics. Engaging in collaborative and group-oriented activities during robotics training offers students valuable opportunities to enhance their creative thinking and problem-solving abilities. The study conducted by [17; 18, 19] supports these conclusions.

The research indicated that students who participated in robotics training displayed notable improvements in various aspects related to creativity, including the fluidity of ideas, flexibility in thinking, innovative approaches, and the ability to provide detailed explanations. The hands-on nature of robotics training enables students to apply their creative thinking skills while designing and constructing robots, fostering their ingenuity and attention to detail. Additionally, the verbal communication and collaborative work involved in robotics training contribute to the development of leadership qualities, social engagement, effective communication across diverse platforms and media, as well as the ability to work efficiently within a team.

Hong and Lin-Siegler (2012) demonstrated that the integration of robotics significantly increased students' interest in physics [18]. This finding highlights the potential of robotics as a tool for making physics more engaging and relevant to students. By providing hands-on experiences and real-world applications, robotics can capture students' interest and motivate them to explore the principles of physics in a practical and meaningful way [18; 20].

Knowledge Gaps and Future Research Directions

While the existing research provides valuable insights into the impact of integrating robotics on students' interest in physics, there are still some knowledge gaps that warrant further investigation. Firstly, the majority of the studies conducted in this area have focused on the effects of robotics integration on girls' sense of belonging and interest in physics. Future research should aim to explore the impact of robotics on boys' interest in the subject as well, as to gain a comprehensive understanding of its effects on all students.

Furthermore, the existing research primarily focuses on the immediate impact of robotics integration on students' interest in physics. Future studies could investigate the long-term effects of robotics integration, examining whether the increased interest and engagement translate into sustained motivation and pursuit of physics-related careers. This would provide valuable insights into the potential of robotics as a catalyst for long-term interest and involvement in the field of physics.

Additionally, while the existing research highlights the positive impact of integrating robotics on students' interest in physics, the specific mechanisms through which this impact occurs remain unclear. Future research could delve deeper into the underlying processes and factors that contribute to the increased interest, such as the role of hands-on experiences, problem-solving skills, and the integration of real-world applications. Understanding these mechanisms would enable educators to design more effective robotics-integrated physics curricula and instructional strategies.

Conclusion

To sum up, these findings emphasize the significance of incorporating innovative teaching methods such as robotics training to enhance students' creativity and learning outcomes. By providing a stimulating and interactive learning environment, robotics training contributes to the holistic development of students and equips them with the necessary skills to thrive in the modern world. Integrating robotics into students' education has been shown to enhance creativity and stimulate new ideas. Robotics serves as a prime example of project-based learning, enabling students to create tangible outcomes based on their tasks. It teaches students how to transform disappointments into innovative solutions and equips them with the ability to tackle more complex problems. Additionally, robotics training not only enhances problem-solving skills but also fosters intellectual growth, prepares students for future job opportunities, and promotes teamwork and collaboration.

Moreover, research findings indicate that the effectiveness of robotics training on students' creativity remains consistent across genders. This suggests that gender does not influence the impact of robotics training on creativity, as both male and female students benefit equally. Teaching robotic structures enhances students' attention and establishes connections between physics lessons and real-life issues. It promotes active participation in learning, utilizes visual methods and organizers, establishes conceptual coherence, facilitates repetition and practice, encourages material exploration and discussion, and makes learning meaningful to students. These strategies contribute to an improved understanding of physics concepts. However, the present study had several limitations, including the need for high-capacity laptops and increased internet bandwidth, limited access to scientific resources, filtering restrictions, lack of parental awareness regarding the significance of robotic tournament certificates, geographical and educational constraints, costs associated with advanced workshop equipment, and unavailability of original software.

In light of these findings, it is recommended to incorporate robotics into the curriculum to enhance students' problem-solving and creative skills. The curriculum should provide opportunities for students to experience a sense of accomplishment through problem-solving and collaborative construction of robotic structures in small and large groups. Additionally, schools should establish robotics workshops and employ professional instructors, engineers, and experts to organize robotics classes in primary and secondary schools. Furthermore, it is suggested to provide incentive programs for students who excel in robotics competitions. Future research should explore the effects of robotics on learning skills and students' creativity in other educational levels, including elementary schools. Comparative studies can also be conducted to leverage the experiences of other countries in this domain.

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