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THE NONPROLIFERATION MENTORSHIP PROGRAM AT SANDIA NATIONAL LABORATORIES

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ABSTRACT

Addressing tomorrow's challenges to the weapons of mass destruction (WMD) nonproliferation and arms controls regimes requires preparing today. In particular, it requires preparing new cadres of professionals with a rigorous understanding of the drivers, dynamics, decisions, and designs that compose the various methods to reduce global WMD-related risks.

In response, over the past nearly 20 years Sandia National Laboratories (Sandia) has engaged in an effort to establish a knowledge transfer mechanism that has manifested into the "Nonproliferation Mentorship Program" (NMP) that has provided early/mid-career professionals an opportunity to gain exposure and expertise in various nonproliferation (NP) subject areas over the last 5 years. Leveraging Sandia's 25+ year experience implementing the Weapons Intern Program, the NMP offers an interdisciplinary depiction of the technical, social, and political dynamics underlying the nonproliferation and arms control regimes. The NMP is currently composed of two phases. Phase I consists of participating in a graduate-level course titled "Weapons of Mass Destruction (WMD) Non-Proliferation Science and Policy." Phase II consists of a capstone project wherein NMP participants apply knowledge gained in Phase I to a short-term research project under the guidance of knowledgeable/expert mentor. The NMP ends with a symposium, wherein the Phase II research results are shared and discussed with a broader audience of interested experts and upper-level leadership. The NMP is developing into a capability that supports a broader set of stakeholders—including the National Nuclear Security Administration and Department of State, among others—with mission objectives in the WMD nonproliferation and arms control regimes.

After situating the NMP among other similar programs, this paper will share the history and development of this unique program and early lessons learned to meet this knowledge transfer challenge. Next, this paper will describe the current structure of the NMP and highlight novel aspects of the program. This paper will then offer some evidence of program success and discuss how various success influenced program development. Lastly, this paper will offer a set of planned, probable, and potential next steps to enhance the capability of Sandia's Nonproliferation Mentorship Program to produce high quality experts prepared to tackle tomorrow's nonproliferation challenges.

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INTRODUCTION

Addressing tomorrow's challenges to the weapons of mass destruction (WMD) nonproliferation and arms controls regimes requires preparing today. This global security landscape is facing new sources of complexity, including quickly shifting geopolitical environments, rapidly changing technological (r)evolution, increasing pressure through privatized development/manufacturing capabilities, and advanced/diversifying threat capabilities. Nonproliferation—particularly in as the large umbrella term used to capture all efforts related to the reducing the risk of potential WMD use—consists of a unique mix of technical, political, and historical challenges. Representative examples include staying on pace with technological advancements (e.g., accounting for how additive manufacturing capabilities may circumvent WMD-prevention regimes), navigating different perceptions of the legality/strength of various treaties (including the Treaty on the Non-Proliferation of Nuclear Weapons [NPT] and the Treaty on the Prohibition of Nuclear Weapons [TPNW]), and addressing legacy issues related to NPT-defined Nuclear Weapons States as permanent members of the United Nations (UN) Security Council.

In response, these challenges require robust and resilient solutions that steer around and coordinate between the various interdependencies and sensitivities related to WMD programs. Such solutions will also need to combine lessons from the past with innovative, state-of-the-art thinking to be developed and deployed effectively. In particular, the require preparing new cadres of professionals with a rigorous understanding of the drivers, dynamics, decisions, and designs that compose the various methods to reduce global WMD-related risks. There are a range of excellent academic and professional development programs related to nonproliferation around the world—the James Martin Center for Nonproliferation Studies at the Middlebury Institute for International Studies at Monterrey, for example—that help meet this human capacity development need.

Yet, in a set of lessons learned from the Weapon Intern Program (WIP) coordinated by Sandia National Laboratories, there is a need to augment such scholarly-focused programs with knowledge transferred from the experience of long-time practitioners. WIP was created in 1998 to "prepare the future generation of experts in nuclear weapons stewardship to assume critical positions in the nuclear weapons community" [1]. The ultimate goal of WIP is to transfer knowledge from experienced weaponeers to accelerate the learning process in all phases of nuclear weapon lifecycles to new generations of stockpile stewards. By leveraging lectures, site visits, and hands-on activities not available in more scholarly programs, WIP provides a unique capacity to prepare experts capable of meeting tomorrow's complexities in stewarding the U.S. nuclear stockpile [2].

Applying this human capacity development to nonproliferation, over the past nearly 20 years Sandia has established a similar knowledge transfer mechanism—the "Nonproliferation Mentorship Program."

HISTORY & DEVELOPMENT

In only its 5th official year, the NMP has provided early/mid-career professionals an opportunity to gain exposure and expertise in various nonproliferation subject areas across Sandia. Similar to

the 25+ year experience implementing the Weapons Intern Program, the NMP offers an interdisciplinary approach to the technical, social, and political dynamics underlying the challenges to effective efforts to reduce WMD-related risks. From its inception, the NMP was centered on Sandia's unique nonproliferation capabilities—namely its deep cadre of related experts, wealth of "on-the-ground" experience, and access to unique nonproliferation-related insights from its stockpile stewardship programs.

Though its current instantiation is relatively new, elements of the NMP have been in development for nearly 20 years. The turn of the millennium ushered in several seismic changes in geopolitical and nonproliferation-related dynamics that drove a need for more experts prepared to address these challenges. A deep understanding of what was needed to "prepare" this next-generation cadre of experts sat in the experience of Sandia experts in (what is now called) the Center for Global Security and Cooperation (CGSC)—who often stood at the forefront of developing novel mitigations to support nonproliferation objectives. In addition to the various technical, geopolitical, and historical details determined necessary, these experts also acknowledged the need to ensure that any associated knowledge transfer mechanism be robust, sustainable, and—if possible—able to provide substantial intellectual rigor. In short—CGSC expert experience in navigating nonproliferation-related challenges wanted to teach the next generation "how to do right things" and not just "how to do things right."

One logical conclusion was to look for a university partner capable of supporting this desired educational focus. Efforts to develop and deploy a more rigorous and academic began with early discussions between Sandia experts and faculty at the University of New Mexico (UNM). Though initially limited to discussions with like-minded political science faculty, a consensus desire for a multidisciplinary course that leveraged expertise across academic departments quickly developed. This ultimately resulted in a semester-long course at UNM—that could be taken for either undergraduate or graduate credit—cross-listed in the political science, nuclear engineering, and chemical engineering departments. Though this course was modified each year to better align the curriculum with the current geopolitical and nonproliferation dynamics of the day, the overall structure and strategy of the course (described in the next section) remained consistent.

What emerged is an intellectually rigorous, multidisciplinary, sustainable course worthy of (and having experienced) university-based accreditation. Despite the success of this course, CGSC experts felt the need for an additional element. After some internal discussions with other Sandia colleagues associated with WIP, the missing element was identified and added—paving the way for the program in place today.

NONPROLIFERATION MENTORSHIP PROGRAM TODAY

Seeking to leverage the additional benefits of tacit knowledge transfer, what is now known as the Nonproliferation Mentorship Program (NMP) consists of two phases. Phase I consists of participating in a graduate-level course titled "Weapons of Mass Destruction (WMD) Non-Proliferation Science and Policy." While the Phase I course is a recent manifestation of a nearly two-decade long university collaboration with the University of New Mexico (UNM), Phase II was introduced and developed over the last five years. Phase II consists of a capstone project

wherein NMP participants apply knowledge gained in Phase I to a short-term research project under the guidance of knowledgeable/expert mentor.

The NMP Phase I course lasts 15 weeks and is typically composed of bi-weekly meeting sessions that include lectures, group discussions, presentations, and practical exercises. The Phase I course curriculum was highlighted by several key factors. First, the course opens with a module that introduces key elements of critical thinking and systems thinking. This provides the participants with tools and frameworks that form the basis of their intellectual journey through the various and complex dynamics related to WMD proliferation. Second, the various historical, political, technical, and practical issues related to WMD proliferation are arranged in an order the emphasizes points of intersection and common patterns. The result is a curriculum that better coordinates a more coherent understanding of the WMD proliferation problem space—and helps better illuminate the boundaries of the current solution space. Lastly, a majority of the WMD proliferation-related topics are taught by subject matter experts who serve as guest lecturers. Combined with primary course instructor who serves as a unifying thread for the course, access to a wide range of experts further enhances the knowledge transfer capacity of NMP's Phase I. The list of lectures from the 2021 NMP Phase I is shown in Table 1, below.

Phase II of the NMP is designed to offer participants an opportunity to apply a part of the knowledge gained in Phase I to real-world WMD proliferation-related problem. Stemming from the success of a similar element for the Fundamentals Course of the Gulf Nuclear Energy Infrastructure Institute [3], these capstone projects serve several purposes to support knowledge transfer. First, they provide opportunities for the participants to demonstrate their increased depth of understanding and analytic capacity related the WMD proliferation. Second, this applied research also provides the primary mechanism by which participants engage with their subject matter expert mentors. Participants are assigned a subject matter expert related to their capstone topic of choice and interact with that mentor to help shape their final capstone product. Over the course of approximately six months, participants and mentors are provided time and resources to meet as formally and frequently as fits in their schedules. Lastly, these capstone projects generate a range of potential solutions to current (and anticipated) WMD proliferation-related problems—many of which form the basis of more formal project proposals, conference papers, and follow-on analysis. Table 2, below, shows the NMP Phase II Capstone projects over the last five years of program operation. (NOTE: The data provided in Table 2 is what NMP coordinators were able to locate and organize at the time of publication.) Over the past few years, the end of the NMP was marked with a symposium, wherein the Phase II research results are shared and discussed with a broader audience of interested experts, line managers, and upper-level Sandia leadership.

Table 1. List of lecture topics & modules for 2021 Nonproliferation Mentorship Program Phase I

Module	Topic
Course Overview and WMD Non-proliferation Challenges	*Course Overview (PI)*
	WMD Non-proliferation Problems, Challenges, and Issues (PI)*
Introduction to Analytical Frameworks	*Critical Thinking Concepts (PI)*
	Systems Approach and Scientific Method: Technical Frameworks for Analyzing the Nonproliferation Problems (PI)
	*Analytical Methodologies (SME**)*
Overview of WMD Threats and Technical Issues	*Chemical Weapons: History, Terminology, Technology, and Conventions (SME)*
	Biological Weapons: History, Terminology, Technology, and Conventions (SME)
	Nuclear Energy: History, Terminology, and Technology (PI)
	Nuclear Weapons: History, Terminology, Technology, and Nuclear Fuel Cycle-(PI)
	WMD Delivery Systems (SME)
Current Approaches to Threat Reduction	*Historical Efforts to Control the Nuclear Fuel Cycle and Introduction to the Integrated Nuclear Safety, Security, and Safeguards (3S) Concept (PI)*
	Nuclear Security and the Convention on Physical Protection of Nuclear Materials (SME)
	The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) and the International Safeguards Regime (SME)
	Arms Control History and Theories (SME)
	Nuclear Deterrence History and Theories (SME)
Current Challenges	*Nuclear Tipping Point (PI)*
	Current NPT Challenges: The Middle East resolution to establish a WMD Free Zone in the Middle East (PI)
	Non-Compliance: Iran and North Korea. What are Potential Regional Impacts? (PI)
	Lessons Learned from Nuclear Nonproliferation Successes. Case studies: South Africa, Libya, Iraq, South Korea and Taiwan. Back to the future? (PI)
	Nuclear Terrorism: How Real is the Threat? (SME)
Addressing the Challenges	*Conflict Management: Track I/II, Think Tanks, and NGOs (SME)*
	Risks Associated with the Global Expansion of Nuclear Energy (PI)
	Reducing Motivations: Connectivity Hypothesis, Discussion and Exercise (SME)
	Nuclear Disarmament Verification Exercise 1 (SME)
	Nuclear Disarmament Verification Exercise 2 (SME
	Tour of the Global Security and Cooperation Center, Sandia National Labs (PI)
	PI = Primary Instructor* * SME = Subject Matter Expert*

Table 2. List of Capstone Projects for Phase II of the Nonproliferation Mentorship Program

Year	Capstone Topics
2016	*The Motivations of Iran to Develop Nuclear Weapons*
	Pakistan and India conflict
	A way to approach nuclear non-proliferation with a state; diplomacy and building trust
2017	*Has the U.S. violated article VI of the NPT?*
	CTBT: A verifiable treaty?
	The Threat of Delivery System Proliferation
	Radiological Risks from Commercial Quantities of Concern
	Proposal for Monitoring Within the Centrifuge Cascades of Uranium Enrichment Facilities
	Should the US Ratify the Comprehensive Test Ban Treaty?
	The Effectiveness of the Joint Comprehensive Plan Of Action (JCPOA) Post Implementation
2018	*Evolution of Optical Sensors for NUDET Detection*
	The Organization for the Prohibition of Chemical Weapons – Counteracting the New Threats from Non-State Actors
	A Deterrence Stability Framework
	IAEA Safeguards and Verification Methods
	U.S. Policy and the Weakening of the Nonproliferation Regime
2019	*China's Belt and Road Initiative: Shifting Economic and Political Influence in the Gulf Cooperation Council States*
	Unintended Impacts of the Export Control Reform Act
	Sanctions and Non-Proliferation
2020	*Risk Reduction in South Asia: How Multilateral Can it Get?*
	Is a Cyber Treaty Possible?
	Analyzing ABACC as a System and Understanding it's Potential Applications
	Integrating Human Centered Design Considerations into Physical Protection Systems
	Novel framework of US and Global Regimes to Counter Infectious Diseases
2021*	*Data-Driven Treaty Verification: A Combined Systems-Based Modeling Approach*
	Lessons Learned from the BWC's Shortcomings & Successes: Implications for the Nuclear Domain
	3S Analysis for Small Modular Reactors
	Safeguards Inspections Prioritization Methodology
**NOTE: Capstone project titles for the 2021 cohort are tentative, since the 2021 Symposium has not been conducted.*	

EVIDENCE OF NMP SUCCESS

Though many benefits of the NMP are intangible, there are a few empirical measures that demonstrate the positive outcomes of the program. For example, Figure 1 (below), illustrates the number of participants in the graduate course that ultimately evolved into Phase I. As shown, there has been a consistent participation from Sandia professionals over the course's existence, as well as fairly consistent participation from UNM students during the 2007 to 2020 time period. Please note that in 2015 the course was not offered for various logistical reasons. In addition, during the 2021 school year, the course was taught only to Sandia professionals and was not offered to any outside (or UNM) students. This sustainment enrollment suggests that both students and working professionals saw value in this element of the NMP and serves as a proxy measure of success. (Note: The data provided in Figure 1 is what NMP coordinators were able to locate and organize at the time of publication.)

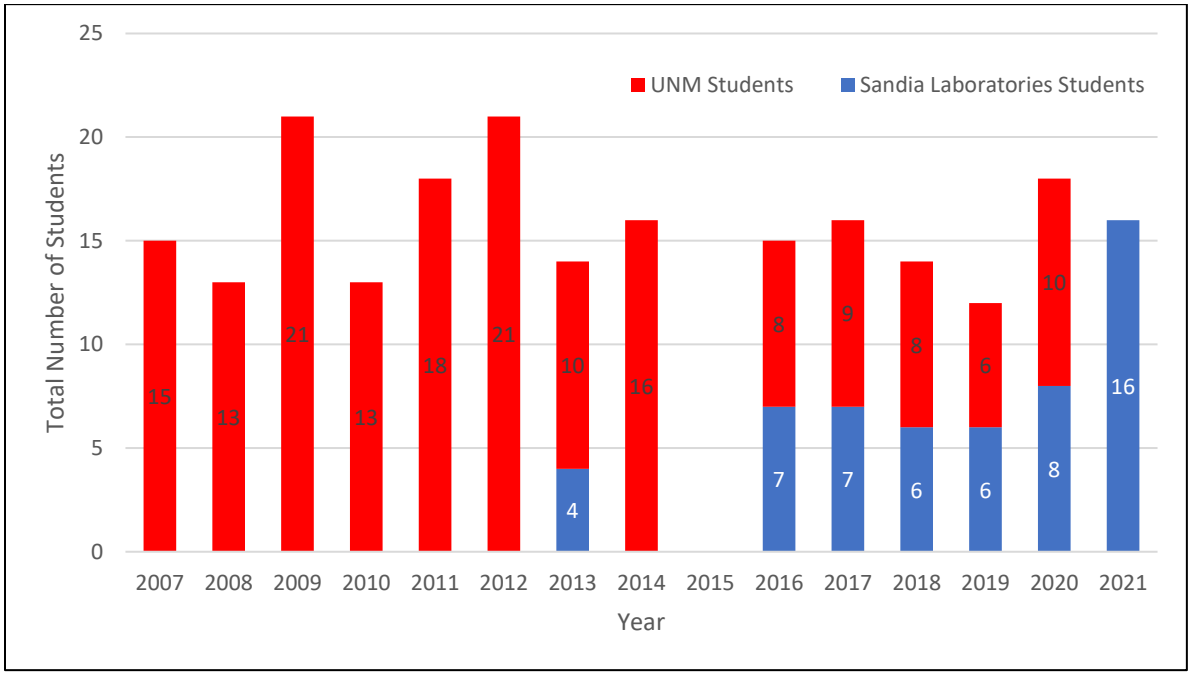

Figure 1. Graph of participation in the graduate course that evolved in Phase I of the Nonproliferation Mentorship Program

Similarly, Figure 2 (below) represents categorical letter grades earned by participants in the NMP-affiliated graduate course. As illustrated, the high number of "A" and "B" grades indicate a high degree of knowledge transfer being experienced in the course, potentially with several possible explanations. It could reflect the benefits of the structure, curriculum, and ethos of the course to successfully transfer WMD proliferation-related knowledge. Likewise, it could reflect the high caliber of participant attracted to the NMP who helped craft a classroom environment that enhanced knowledge transfer. Though anecdotal, the NMP coordinators contend that the results in Figure are reflective of both described causes.

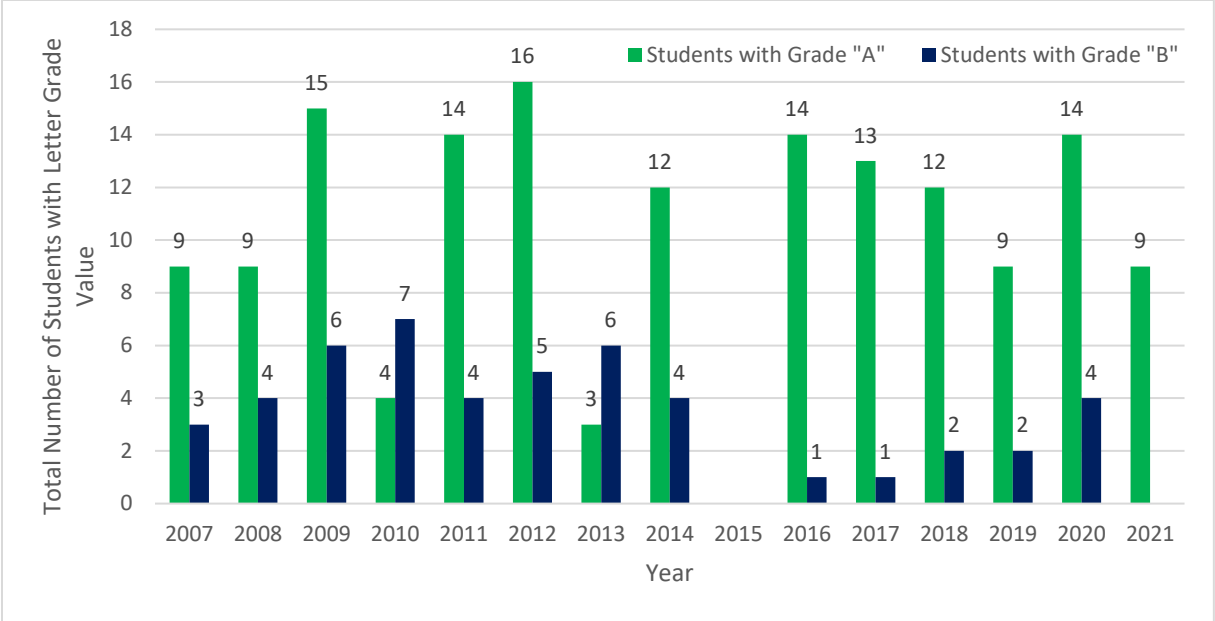

Figure 1 Graph of categorized letter grades for participants in the graduate course that evolved in Phase I of the Nonproliferation Mentorship Program

Yet, the more direct measure of NMP effectiveness resides in direct quotes and comments from former (and current) participants. The following is representative snapshot of the responses elicited from NMP participants:

- *The NMP allowed me to expand my knowledge related to WMD and nonproliferation. This course helped enhance my professional career and understand how the physical security of nuclear material reduces the risk of proliferation and potential for WMD creation* – Senior nuclear engineer in international nuclear security

- *The Nonproliferation Mentoring Program...course encourages broad-minded critical thinking and new idea generation. It gave me an understanding of the mission space that otherwise would have taken me years to gain* – Senior project controller and business management professional

- *As an experienced biologist with some familiarity of the history and current non-proliferation efforts involving biological and chemical weapons, I knew that the [NMP] course would likely greatly expand my knowledge on nuclear non-proliferation history and status of current treaties, which it truly did. What surprised me, however, was that as a published author of dozens of scientific articles, I learned so much on translating the use of the scientific method into persuasive oral and written arguments. The class really honed my skills as a critical reader, speaker, author and presenter* – Senior engineering program lead in biosafety & biosecurity

- *Although I had ten years of industry experience in space and ground systems, I lacked insight into the history, politics, and science of WMDs and related treaties. The NMP provided me with an opportunity to dive into the context behind nuclear non-*

proliferation. The combination of the course work and capstone project through NMP helped solidify the connection between academic knowledge and the mission work I supported. This context continues to serve me well in my career – Research & Development manager in distributed sensing systems mission engineering

- *I participated in the NMP as an early career chemical nonproliferation professional and left with a clear view of the entire nonproliferation landscape. I learned many foundational tenets of nonproliferation that would have taken years to acquire organically through my work. The entire program…deepened my ability to think critically and generate original solutions. The instructors were excellent, freely shared their bounties of knowledge, and provided access to renown subject matter experts. My professional network has grown significantly thanks to participation in this program and my visibility into potential career opportunities has widened. I'm thankful I was able to participate!* – Senior chemist in chemical weapons security & nonproliferation

Additional evidence of NMP success relates to the professional impact the program had on participants *after* completion, which included:

- Approximately 25% of students who took the course decided to continue their education into a nonproliferation-related field;
- Another 10% of students changed their career paths to seek employment into nonproliferation-related fields; and,
- Past participants have become nonproliferation advisors for U.S. national security agencies.

NMP NEXT STEPS

The recent successes of the NMP have established a strong reputation for the program, as well as several areas for potential program expansion. One area potential expansion is to work to identify either (other both) additional university partners or develop new academic credentials. To date, NMP participants have taken the Phase I course either for graduate university-based credit (e.g., credits that could be applied to master's degree) or for professional development credit. Along these lines, NMP coordinators will evaluate different hybrid education models, with an aim to leverage lessons learned from virtual offerings operations during COVID-19 responses to increase program flexibility in the future. Another area of potential expansion involves investigating opportunities to expand NMP participation. NMP coordinators support the premise that including a more diverse group of participations will enhance the educational experience of the program. To that end, current efforts are investigating various procedural and logistical challenges to offering NMP participation to a range of stakeholders related to the U.S. nuclear security enterprise—as well as identifying and developing creative solutions in response.

Building off demonstrated success to date, planned and potential next steps are oriented toward enhancing the capability of Sandia's Nonproliferation Mentorship Program to produce high quality experts prepared to support a broader set of stakeholders—including the National Nuclear Security Administration and Department of State, among others—to tackle tomorrow's WMD proliferation challenges.

REFERENCES

[1] J. Whitley and L. Schoof, “Sandia National Laboratories Weapon Intern Program (WIP): Preparing Weaponeers from across the NSE,” Presentation, SAND2013-4404C, 2013.
[2] S. Holinka, “Weapon Intern Program graduates 25th class,” Sandia Lab News, August 13th, 2020.
[3] A.D. Williams, A.A. Solodov, A.H. Mohagheghi, P.A. Beeley, and S. Alameri, “The Gulf Nuclear Energy Infrastructure Institute: A Multidisciplinary Educational Approach for Integrated Nuclear Energy Safety, Security and Safeguards in the Middle East,” Journal of Nuclear Materials Management, XLVII (1), p. 4-21, 2020.